Chapter 5: Flood, Earthquake and Sea-Level Rise Risk Management

1 Overview and Key Findings

The present-day Delta is defined geographically and hydraulically by levees, creating a landscape that differs from that of the historic, natural Delta. In place since the early 20th century, the current-day levee system provides flood control, channels water for urban and agricultural uses, and creates an environment unique in California. According to the Delta Reform Act of 2009, it is the policy of the State to “protect, maintain, and, where possible, enhance and restore the overall quality of the Delta environment, including, but not limited to, agriculture, wildlife habitat, and recreational activities” and also to “improve flood protection by structural and non-structural means to ensure and increased level of public health and safety.”[1]These goals require a robust levee system.

For the purposes of this plan, an up-to-date map of Delta levees was created. This map serves as the basis for an updated tabulation of levee lengths, which shows that in the Legal Delta, there are just under 1,000 miles of permanently maintained levees, of which 380 miles are project levees constructed or improved by the U.S. Army Corps of Engineers (USACE), and an additional 63 miles are urban non-project levees, as defined by recent state legislation. Within the overall total, there are 613 miles oflowland levees, defined as those leveesthat protect lands in the Delta that are below sea level. The lowland levees are the levees that are most critical to the preservation of the Delta and to achieving the coequal goals of water supply reliability and ecosystem restoration. Of these lowland levees, 143 miles are project leveeslocated largely along the Sacramento River. The remaining 470 miles of non-project lowland levees need to be maintained and enhanced primarily by the State and the local reclamation districts.

Of the 470 miles of non-project, lowland levees, less than 100 miles fall below FEMA’s Hazard Mitigation Plan (HMP) “standard” and another 100 miles or so are already at or about the Corps of Engineers Delta-specific PL 84-99 standard. While the first priority should be to bring all Delta levees up to at least the HMP standard, it has been the goal of the state and federal governments, working through the Department of Water Resources (DWR), the U.S. Army Corps of Engineers (USACE), and the local reclamation districts, to meet the higher Delta-specific PL 84-99 standard since 1982 when DWR and USACE produced ajoint report on the Delta levees which recommended the basis for this standard. Funds currently available from the Federal government, voter-approved state bond measures, and local cost shares should bring all Delta levees close to achieving this goal. When funds currently in the immediate pipeline have been expended,more than $698million will have been invested in improvements to the Delta levees since 1973. These improvements have created significantly improved Delta levees through modern engineering and construction, making obsolete the historic data that is still sometimes used for planning or predicting rates of levee failure.

Three approaches can help all jurisdictions and planners further reduce the risks resulting from the failure of the Delta levees. These approaches are: (1) build even more robust levees, (2) improve regular maintenance and inspections, flood-fighting at times of high water surfaces and emergency response following earthquakes, and (3) improve preparedness for dealing with failures after they occur. With regard to the first approach, the big question with respect to the lowland Delta levees is not whether they should be improved to the Delta-specific PL 84-99

[1] Delta Reform Act, 2009, W.C. 29702 (b), (d)

standard—thatis already happening—butwhether they should be improved to a higher standard in order to address hazards posed by floods, earthquakes, and sea-level rise. These improvements would also allow for planting vegetation on the water side of the levees—an essential component Delta ecosystem repair. These further-improved levees would have wider crowns to provide for two-way traffic and could easily be further widened at selected locations to allow the construction of new tourist and recreational facilities out of the statutory floodplain. Improvement of most lowland levees and selected additional levees to this higher standard is estimated to have base engineering and construction costs of $1-2 billion. Enhancements for ecosystem restoration and other purposes and program management could increase the cost to as much as $4 billion. In addition, it is suggested that $50 million per year should be provided for continuing maintenance and inspections and emergency preparedness, response and recovery and that a single Delta region-centric agency should assume the responsibility for allocating this funding. Three broad sources of funding and economic justifications for the investments are discussed later in this chapter

These estimated costs are not dissimilar to that of the "Fortress Delta" strategy described in the 2007 "Envisioning Futures" report by the PPIC as one of the alternatives for increasing water supply. Provision of water supply reliability through improvement of the levee system now appears to be significantly cheaper than the proposed isolated conveyance. Regardless, a further-improved levee system will make a significant contribution to the achievement of the coequal goals of water supply reliability and ecosystem restoration that were stated in the Delta Reform Act rather than impeding it.

2 Background

The history of the Delta levees is relatively well-known (Thompson, 1957;[2]The Delta Atlas, 1995;[3]Mount and Twiss, 2005;[4] DRMS, 2009'[5] Delta Stewardship Council Flood Risk White Paper, 2010;[6] Zuckerman, 2011[7]) and is not repeated in its entirety here. Some of the levees in the Delta are flood-control project levees, built by the federal government and turned over to the State for maintenance, but most of the Delta levees were built or re-constructed and are maintained by local reclamation districts. There are only a few levees that are not maintained by local reclamation districts and are thus privately owned and maintained. The State has also passed responsibility for maintenance of most of the flood-control project levees to the local reclamation districts although it directly maintains some of the levees on the Sacramento River. Regardless of the State now relying on local reclamation districts for the execution of much of the work on Delta levees, much of this work is supported with state funds in recognition of the State's long-term interests and obligations. These obligations flow in part from the State's acceptance of the grant of federal lands in accordance with the Swamp and Overflowed Lands Acts. For example, in Kimball v. Reclamation Fund Commissioners,[8] the Supreme Court of

[2] Thompson, J.,*Settlement Geography of the Sacramento-San Joaquin Delta*, *California,*Ph.D. dissertation, Stanford University, 1957.

[3]http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm

[4] Mount, J.F. and R. Twiss, *Subsidence, sea level rise, seismicity in the Sacramento-San Joaquin Delta*, San Francisco Estuary and Watershed Science, v. 3, article 5, 2005.

[5] California Department of Water Resources, Delta Risk Management Strategy Final Phase 1 Report,2009, http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase1_information.cfm

[6] Delta Stewardship Council, Flood Risk White Paper, 2010, http://deltacouncil.ca.gov/delta-plan.

[7] Zuckerman, T., Comments on the Third Staff Draft of the Delta Plan, Delta Stewardship Council, 2011, http://deltacouncil.ca.gov/public-comments/read/195

[8] 45 Cal. 344, 1873

California held that he, Kimball "must be held to have known, when he took the title, that the State, by accepting the grant, had assumed an obligation to reclaim the land, and that it had already inaugurated a system for that purpose. He was bound in law to take notice of the public statues above mentioned, and must be deemed to have accepted the title in subordination to the paramount right and duty of the State to cause the land to be reclaimed. He cannot now, therefore, be permitted to set up his own wishes, nor his private interests, in opposition to the performance, by the State, of the obligation which it assumed to the Federal Government."

A good summary of the history and current status of the Delta levees is also provided in a technical memorandum prepared for the Department of Water Resources (DWR) by outside consultants,[9] and referenced subsequently as the DWR Technical Memorandum (2011). The Technical Memorandum finds that the existing Delta levees comprise a system and that it is misleading to evaluate the value of individual levees or islands without considering the benefits that the overall system of levees provides, and that the Delta levees now protect much more than agriculture. In this respect the draft Technical Memorandum is simply repeating points made in the CALFED Levee System Integrity Program Plan,[10] which said:

> *The benefits of an improved Delta Levee system include greater protection to the Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and conveyance benefits. The wide range of beneficiaries of the Delta Levee System Integrity program include Delta local agencies; landowners; farmers; boaters; wildlife; and operators of railroads, state highway, utilities, and water distribution facilities. Delta Water users and exporters also benefit from increased protection to water quality. Federal interests benefit from improvements to conveyance, navigation, commerce, and the environment, and from reduced flood damage.*

In the language of the draft Technical Memorandum:

> *While some reports propose leaving islands flooded or state that it is too expensive to continue a state grants program for levee maintenance, the fact remains that a large portion of the state economy is dependent on export water, which in turn is dependent upon the Delta levees for preservation of water quality and for conveyance. If a decision were made today to address this single issue, it would require more than a decade before an alternative conveyance could be in place. During all of that time the purity and availability of export flow would remain dependent on the Delta levee system. Delta levees provide protection for a wide variety of benefits. If levees fail and several islands were flooded, adverse consequences would be expected far beyond direct loss due to flooding on islands and tracts. Most island surfaces are so far below sea level that the resulting deep water would contrast markedly with the 1850 "natural" Delta. The water body created by a levee failure may be good habitat for some species and poor habitat for others. Tidal exchange from Suisun and San Francisco Bays would be increased and Delta salinity would be likely to rise at least during dry seasons and dry years. Water supply conveyance to remaining Delta islands, to Contra Costa County, and to the State*

[9] California Department of Water Resources, Staff DRAFT, "Background/Reference Memoranda, Delta Region Integrated Flood Management Key Considerations and Statewide Implications," July 15, 2011. This document was released for limited public review on July 15, 2011. Both the technical memorandum and the related "Framework for Department of Water Resources Investments in Delta Integrated Flood Management" are in draft form and are subject to change, but the basic findings of the technical memorandum are unlikely to change and several of its findings are mentioned herein.
[10] http://calwater.ca.gov/content/Documents/library/305-1.pdf

Water Project and the Central Valley Project may be disrupted by salinity intrusion some of the time. Infrastructure systems, including Delta highways and pipelines, might be blocked. Delta towns and their economic activity might be jeopardized. Adjacent islands would become much more vulnerable due to seepage or increased wave action.

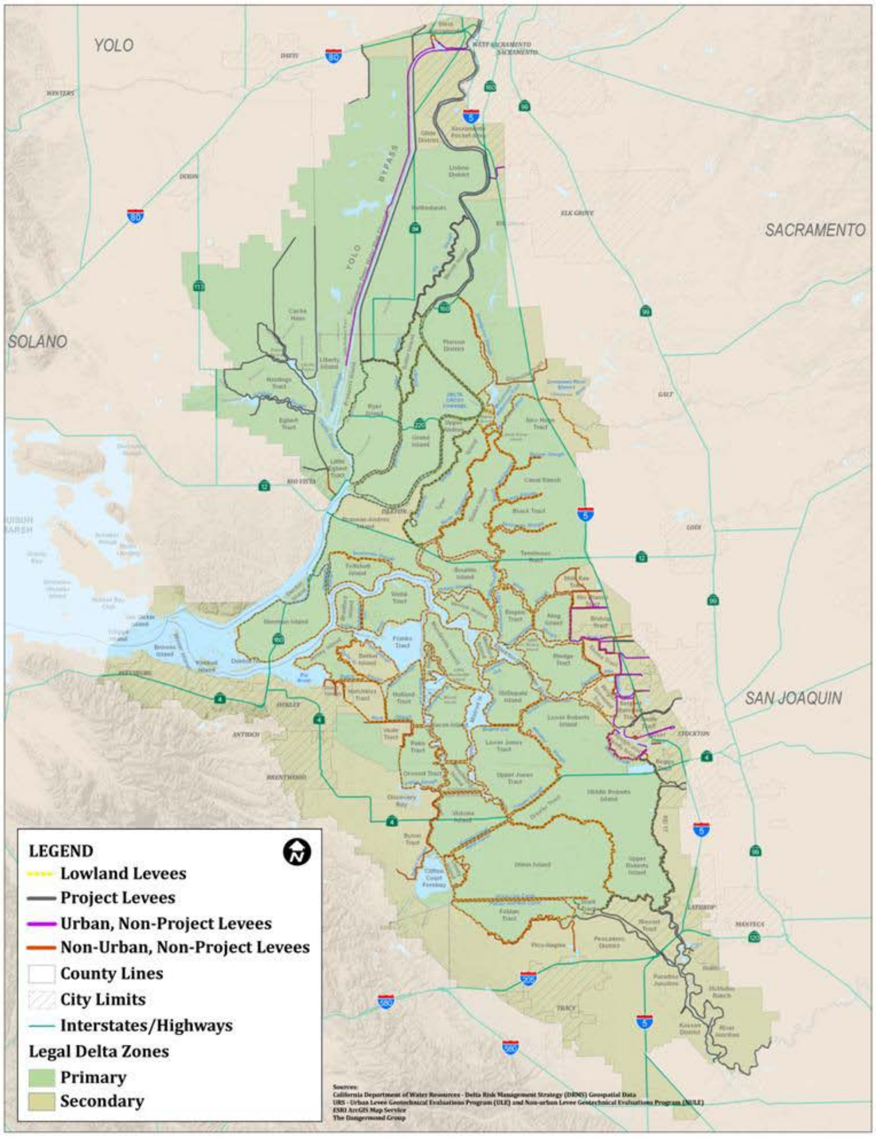
The principal Delta levees that are currently being maintained are shown in Figure 10 and are listed in Table 1. Previous listing of Delta levees have been provided in the Table 6 of the Delta Atlas and in Table 3 of The CALFED Levee System Integrity Program Plan, but these listings and any accompanying maps are not available in electronic form and the accuracy of some of the mileages involved is questioned by reclamation district engineers. Therefore, in order to provide a table that was consistent with a current map, an updated listing was prepared as part of this study. DWR does not maintain a centralized GIS system, but with the help of DWR staff three different GIS data sets, all based on the 2007 LiDAR surveys conducted for DWR, were obtained from two different offices of URS Corporation. The most complete of thesewas labeled “Division of Flood Management” and this was used as starting point in developing an updated map. However, because many embankments which do not represent levees that are currently being maintained, are height-limited levees, or are dry levees that are not critical to flood protection, were mapped as levees, these were deleted. Canal embankments were not mapped as levees in this data set but the embankments on either side of the Delta Cross Channel and the northern side of the Contra Costa Canal on Hotchkiss Tract have been counted as flood-control levees in our compilation.In a GIS system all lines are modeled as segments whose lengths can be calculated automatically so that the total lengths around each island or tract can readily be obtained and these are the lengths that are shown in Table 1. Thus the map in Figure 10 and the lengths listed in Table 1 are consistent with each other. To the extent possible, the lengths have been cross-checked with ground survey data provided by reclamation district engineers.[11]

By way of comparison with Figure 10, a reconstruction of the historic Delta based on Atwater (1982)[12] is shown in Figure 11. Figure 11 shows that the historic Delta contained no large expanses of open water, but instead was comprised of a dendritic system of channels and sloughs that traversed generally marshy terrain. Natural levees, created along the edges of major waterways, were overtopped only in high water events and supported riparian and even upland vegetation. When the modern Delta was created by diking and dredging in the late 19th century and very early 20th centuries, some of the man-made levees were constructed over the natural levees, but many were not. Those waterways that were created by dredging do not have bordering levees that were founded on natural levees. In many other cases the modern levees were not sited directly over the natural levees. Sketches developed by KSN Inc. illustrating the history of development of both the dredger cuts and other modern levees are shown as Figures 12 and 13.

[11]Copies of Figure 10 and some of the subsequent figures in this chapter are not particularly legible when reproduced at normal report size but high resolution copies may be obtained by following the instructions on the DPC web site. These figures have been designed for use as wall posters with dimensions of about 3 by 4 feet.

[12]Atwater, B., Geologic Maps of the Sacramento-San Joaquin Delta, California, USGS Miscellaneous Field Studies Map MF-1401, 1982.

Figure 1 Delta Levees[13]



[13] For high resolution image see http://forecast.pacific.edu/desp-figs.html

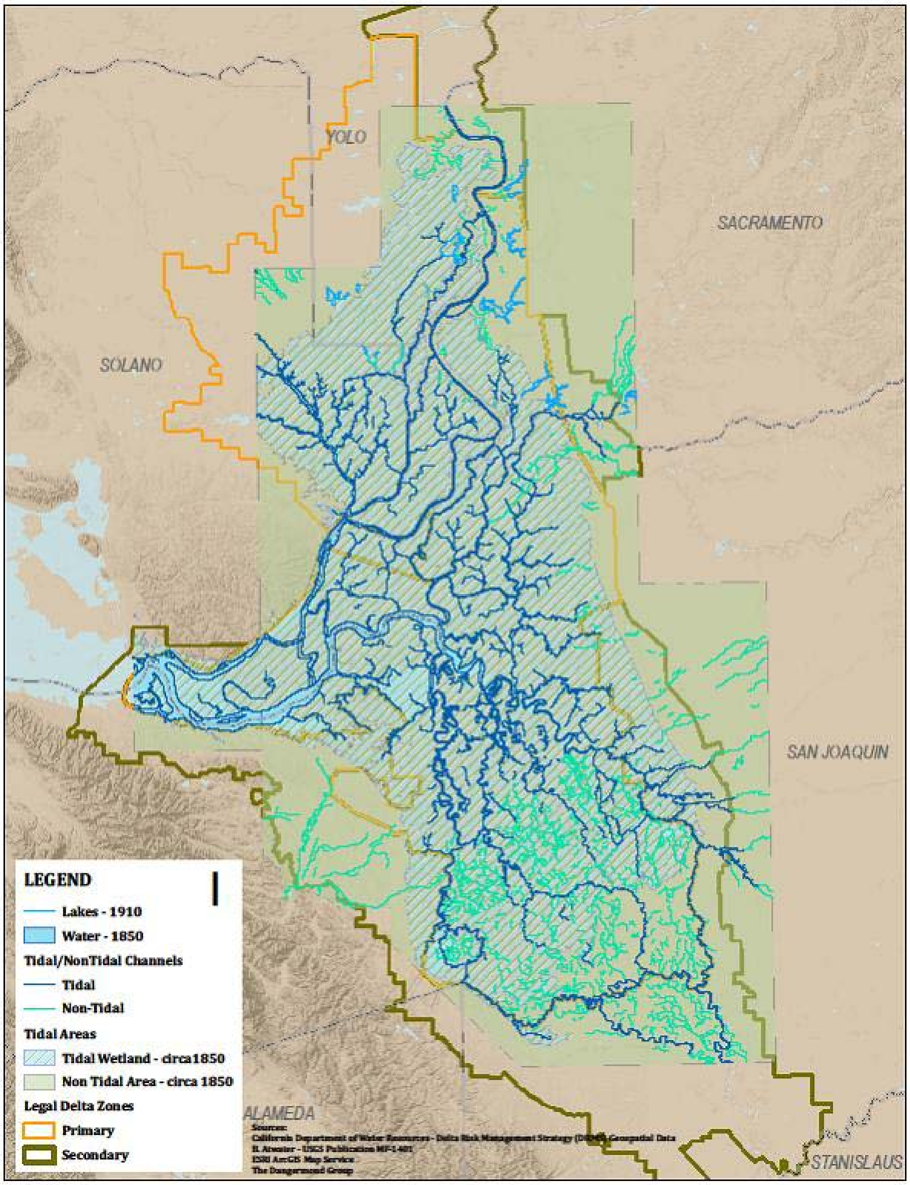
Table 1 Delta Levees (Part 1 of 2)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(I)
List Number	District Number	Reclamation District	Miles of Levee				
			Project	Urban NP	NP-NU	Total	Lowland
1	556	Andrus Island	11.2	0.0	0.0	11.2	Yes
2	2126	Atlas Tract	0.0	2.3	0	2.3	No
3	2028	Bacon Island	0.0	0.0	14.3	14.3	Yes
4		Bear Creek	3.3	0.0	0.0	3.3	No
5		Bethel Island	0.0	0.0	11.5	11.5	Yes
6	2042	Bishop Tract	0.0	6.5	1.6	8.1	No
7	404	Boggs Tract	4.0	0.6	0.6	5.2	No
8	756	Bouldin Island	0.0	0.0	18.0	18.0	Yes
9	2033	Brack Tract	0.0	0.0	10.0	10.0	Yes
10	2059	Bradford Island	0.0	0.0	7.4	7.4	Yes
11	317/407	Brannan-Andrus	17.5	0.0	10.1	27.6	Yes
12	800	Byron Tract	0.0	0.0	9.5	9.5	No
13	2098	Cache Haas	10.9	0.0	0.0	10.9	No
14	2086	Canal Ranch	0.0	0.0	7.5	7.5	Yes
15	2117	Coney Island	0.0	0.0	5.5	5.5	Yes
16	2111	Dead Horse Is.	0.0	0.0	2.6	2.6	Yes
17	2137	Dutch Slough	0.0	0.0	4.1	4.1	No
19	536	Egbert Tract	10.6	0.0	1.8	12.4	No
20	813	Ehrheart	1.8	0.0	3	4.8	No
21	2029	Empire Tract	0.0	0.0	10.5	10.5	Yes
22	773	Fabian Tract	0.0	0.0	18.8	18.8	Yes
23	2113	Fay Island	0.0	0.0	1.6	1.6	Yes
24	1002	Glanville Tract	0.0	0.0	7.1	7.1	No
25	765	Glide	1.7	0.0	0.0	1.7	No
26	3	Grand Island	28.7	0.0	0.0	28.7	Yes
27	2060	Hastings Tract	15.6	0.0	0.0	15.6	No
28	999	Netherlands	32.2	0	0	32.2	No
29	2025	Holland Tract	0.0	0.0	11.0	11.0	Yes
30	799	Hotchkiss Tract	0.0	0.0	8.8	8.8	Yes
31	830	Jersey Island	0.0	0.0	15.5	15.5	Yes
32	2038/2039	Jones Tract	0.0	0.0	18.4	18.4	Yes
33	2085	Kasson	6.3	0.0	0.0	6.3	No
34	2044	King Island	0.0	0.0	9.1	9.1	Yes
35	369	Libby McNeil	1.0	0.0	2.8	3.8	Yes
36	1608	Lincoln Village	0.0	3.3	0.6	3.9	No
37	307	Lisbon	6.6	0.0	0.0	6.6	No
38		Maintenance Area 9	12.6	1.5	0.0	14.1	No
39	2027	Mandeville Island	0.0	0.0	14.3	14.3	Yes
40	2030	McDonald Island	0.0	0.0	13.7	13.7	Yes
41	2075	McMullin	7.4	0.0	0.0	7.4	No
42	2041	Medford Island	0.0	0.0	5.9	5.9	Yes
43	150	Merritt Island	17.7	0	0	17.7	No
44	2107	Mossdale 2	4.3	0.0	0.0	4.3	No
45	17	Mossdale Tract	15.8	0.0	0.0	15.8	No
46	348	New Hope Tract	0.0	0.0	15.1	15.1	Yes
47	2064	Palm-Orwood Tract	0.0	0.0	14.4	14.4	Yes
48	2095	Paradise	4.9	0.0	0.0	4.9	No

Table 2 Delta Levees (Part 2 of 2)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(I)
List Number	District Number	Reclamation District	Miles of Levee				
			Project	Urban NP	NP-NU	Total	Lowland
49	2058	Pesadero Tract	6.6	0.0	0	6.6	No
50	2104	Peters	6.8	0.0	0.0	6.8	No
51	551	Pierson District	6.8	0.0	7.3	14.1	Yes
52	1007	Pico-Naglee Tract	0.0	0.0	9.5	9.5	No
53	2090	Quimby Island	0.0	0.0	7.0	7.0	Yes
54	755	Randall	1.8	0.0	0.0	1.8	No
55	744	Rec District	3.9	0.0	0.0	3.9	No
56	673	Rec District	0.2	0.0	0.0	0.2	No
57	2037	Rindge Tract	0.0	0.0	15.8	15.8	Yes
58	2114	Rio Blanco Tract	0.0	1.8	4.1	5.9	No
59	2064	River Junction	9.7	0.0	0.0	9.7	No
60	524/544/684	Roberts Island	16.4	0.0	34.1	50.5	Yes
61		Rough/Ready Island	0.0	5.5	0.0	5.5	No
62	501	Ryer Island	20.2	0.0	0.0	20.2	Yes
63	2074	Sargent Barnhart	2.1	2.9	2.5	7.5	No
64	341	Sherman Island	9.6	0.0	9.9	19.5	Yes
65	2115	Shima Tract	0.0	7.0	7.3	14.3	No
66		Shin Kee Tract	0.0	0.0	7.0	7	No
67	1614	Smith Tract	5.9	3.3	1.0	10.2	No
68	2089	Stark	2.8	0.0	0.8	3.6	Yes
69	38	Staten Island	0.0	0.0	25.4	25.4	Yes
70	2062	Stewart Tract	12.2	0.0	0.0	12.2	No
71	349	Sutter Island	12.4	0.0	0.0	12.4	Yes
72	548	Terminous Tract	0.0	0.0	16.1	16.1	Yes
73	1601	Twitchell Island	2.5	0.0	9.3	11.8	Yes
74	563	Tyler Island	12.1	0.0	10.3	22.4	Yes
75	1	Union Island	1.1	0.0	28.8	29.9	Yes
76	2065	Veale Tract	0.0	0.0	5.0	5	No
77	2023	Venice Island	0.0	0.0	12.4	12.4	Yes
78	2040	Victoria Island	0.0	0.0	15.1	15.1	Yes
79	554	Walnut Grove East	0.9	0.0	2.5	3.4	Yes
80	2094	Walthall	3.2	0.0	0.0	3.2	No
81	2026	Webb Tract	0.0	0.0	12.9	12.9	Yes
82	828	Weber	0.0	1.7	0.6	2.3	No
83	900	West Sacramento	15.0	26.6	1.6	43.2	No
84	2096	Wetherbee	0.2	0.0	0.0	0.2	No
85	2072	Woodward Island	0.0	0.0	8.9	8.9	Yes
86	2119	Wright-Elmwood Tract	0.0	0.0	7.1	7.1	Yes
87	2068	Yolano	8.8	0.0	0.0	8.8	No
88		Yolo Bypass Unit 4	4.2	0.0	0.0	4.2	No
	Lowland Total		143.2	0.0	470.5	613.7	
	Grand Total		379.5	63.0	537.4	979.9	

Figure 2The Historic Delta[14]



[14] For high resolution image see http://forecast.pacific.edu/desp-figs.html

It is well known that many of the Delta islands have subsided since they were first diked so that most of the land surfaces within these islands are now below sea level. However, the rates of subsidence have decreased markedly in recent years. That issue is discussed in more detail in Appendix E. Reasonably current land surface elevations interpreted from DWR's 2007 LiDARsurveys are shown in Figure 14.[15]The mostly deeply subsided land is about 30 feet below sea level, but only a fraction of the Legal Delta is more than 15 feet below sea level, as shown by the dark blue coloring in Figure 14. The subsidence has been restricted to the areas of the western and central Delta that are underlain by peat. There are also extensive areas to the north and the south within the Legal Delta that have not been affected by subsidence.

Figure 3 Construction of Delta Levees

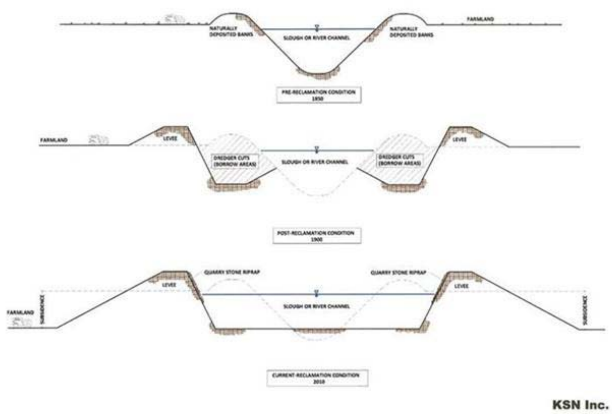
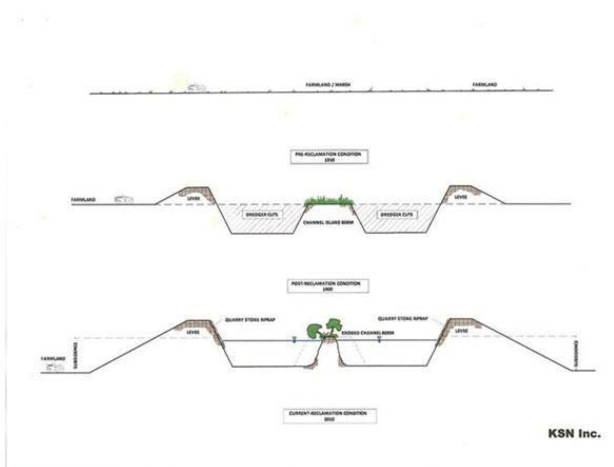
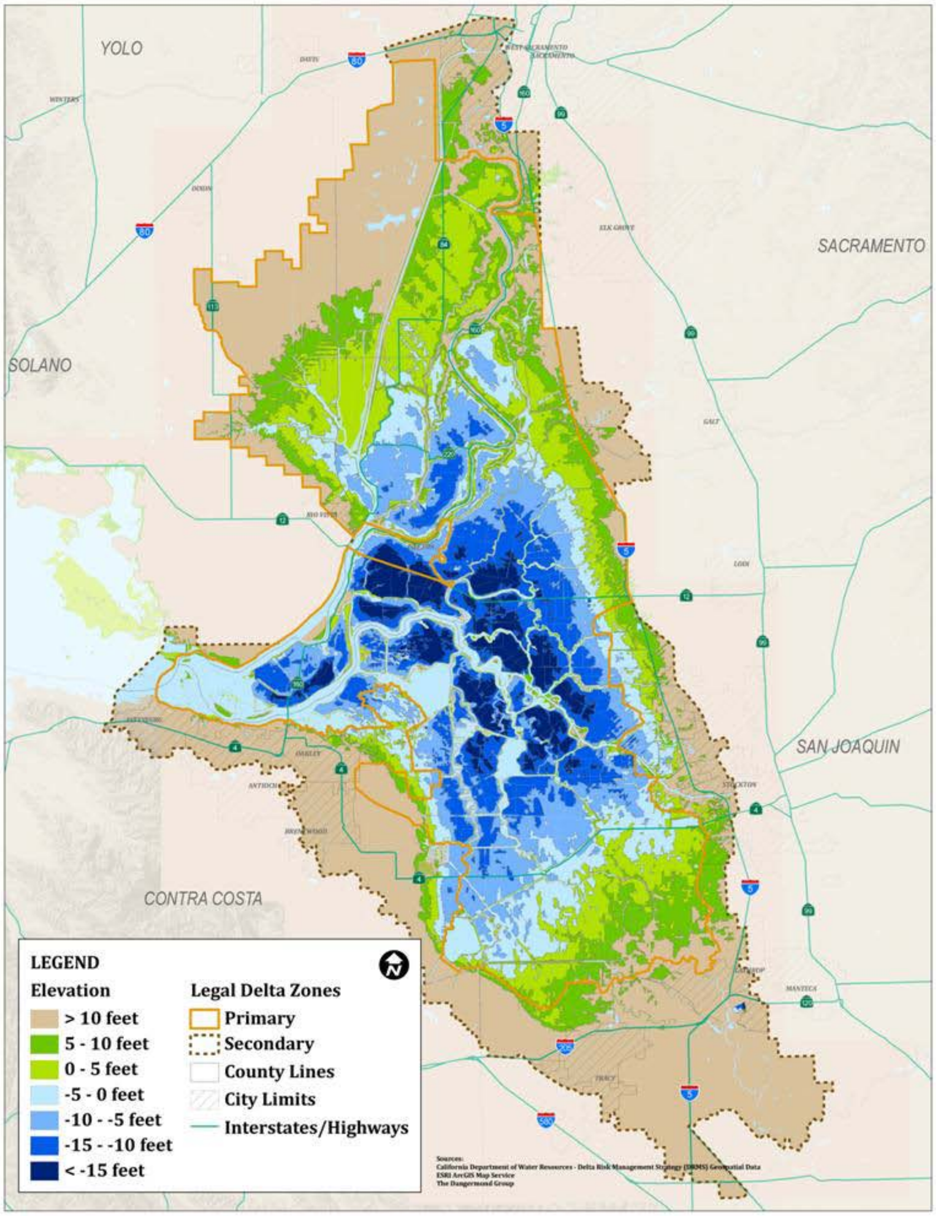


Figure 4 Construction of Dredger Cuts



[15] Based on DRMS GIS data set developed by URS Corporation and provided by DWR.

Figure 5 Current Elevations of Delta Land Surface[16]



[16] For high resolution image see http://forecast.pacific.edu/desp-figs.html

There is a popular impression that there are 1,100 miles of Delta levees all in poor condition. This has led to concern that there is a high probability of widespread failures in the event of flooding, earthquakes, or sea-level rise. While most Delta levees need further improvement, many miles of the Delta levees are actually in quite good condition.[17]

Only the levees within the Legal Delta that are currently being maintained and are candidates for further improvement are shown in Figure 10. Levees such as those around Liberty Island and Prospect Island, which lie within the Yolo Bypass, and the levees around the McCormack-Williamson Tract, which have always been height limited and are slated for removal, are not shown. With the removal of levees that are not being maintained and dry-land levees, the total length of the Delta levees is 980 miles, that is, just under 1,000 miles. The division of these levees into project, non-project urban, and other non-project levees and their significance is explained in the following sections. While the levees can be broken into different classifications, it is important to recognize that they all work together as a system. The draft DWR Technical Memorandum (2011) states: "The Delta's system of levees … andinterconnected channels operate as a single, multi-function, flood management system. The failure of one levee can increase the risk of other levee failures, increasing the need for levee maintenance on adjoining islands in an effort to prevent additional levee failures. In addition, the large benefits to regions outside the Delta make it difficult to consider one island or tract separately from all others."

3 Status of Delta Levees

3.1 Categories of Levees

3.1.1 Project Levees

Project levees were constructed or improved by the U.S. Army Corps of Engineers (USACE) as part of federal-state flood-control projects and were turned over to the State for operations and maintenance. The State has in turn generally passed on the responsibility for routine maintenance to local reclamation districts, although the Paterno Decision[18] confirmed the State's continued basic liability with respect to these levees. The State Plan of Flood Control Descriptive Document, dated November 2010, delineates project levees and provides the names of the local maintenance agencies. Project levees within the Delta, as delineated in the GIS data set obtained through DWR, are identified in Figure 10. These levees were built to standards that generally exceed the PL 84-99 criteria described below.

3.1.2 Urban Levees

SB 5,[19] enacted in 2007, calls for a minimum of 200-year flood protection for urban and urbanizing areas in the Sacramento-San Joaquin Valley. SB 5 also limits the conditions for further development if this level of flood protection has not been achieved, conditions have not been imposed on the development to provide this level of flood protection, or adequate progress towards achieving this level of protection cannot be shown. DWR is developing criteria for these

[17] Selected photographs taken during a period of relatively high water in March 2011 are shown in Appendix C.
[18] *Paternov. State of California* (2003)113 Cal.App.4th 998.
[19] SB 5 (Machado) was the centerpiece of a far-reaching flood-control package of legislation. It requires the Department of Water Resources to prepare a Central Valley Flood Protection Plan and allows local jurisdictions to prepare their own plans only if they include specified elements that are consistent with the state plan.

urban levees that will generally be more stringent than the current criteria for project levees. These criteria are discussed below.

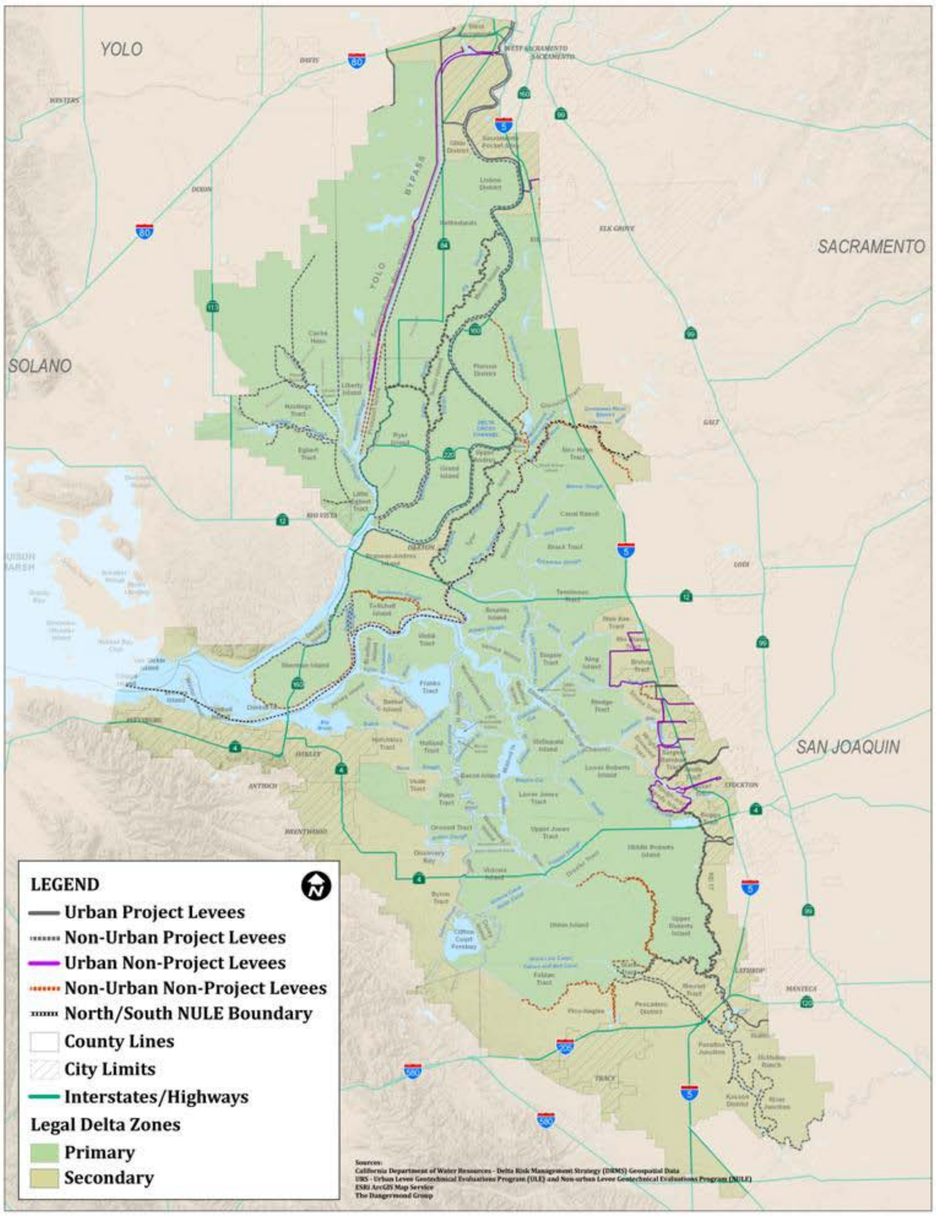
Recognizing the need for higher levels of flood protection, the major urban areas in the Sacramento-San Joaquin Valley have each formed a Joint Powers Authority (JPA) to implement levee improvements, in part using funds from the DWR Early Implementation Program. Three of these JPAs overlap the Legal Delta—West Sacramento Area Flood Control Agency (WSAFCA), Sacramento Area Flood Control Agency (SAFCA), and San Joaquin Area Flood Control Agency (SJAFCA).

Prompted by the Paterno Decision and SB 5, DWR is undertaking a major investigation of both riverine and Delta levees that is divided into two components, the Urban Levee Evaluations (ULE), and the Non-Urban Levee Evaluations (NULE) (Inamine et al., 2010).[20]These evaluations include detailed site investigations and some analyses and are intended to inform the Central Valley Flood Protection Plan (CVFPP) as to the likely level of effort that will be required for final design and the construction of improvements. Those levees within the legal Delta that are included in ULE and NULE, as identified in a GIS data set specifically obtained through DWR for this purpose, are shown in Figure 15,[21] superimposed on the mapping of project and non-project levees. Some of these DWR-designated urban levees are project levees and some are not. Because there are special requirements for urban levees, as well as special sources of funding for improvements, the urban levees that are not also project levees are identified in Figure 10 and Table 1. There are a total of 122 miles of urban levees in the Delta of which 63 miles are non-project levees.

[20] Inamine, M. et al., California's Levee Evaluation Program, US Society of Dams, 30th Conference, Sacramento, April 2010.

[21]Based on GIS data set provided by DWR and URS Corporation.

Figure 6 Urban and Non-Urban Levee Evaluation Programs[22]



[22] For high resolution image see http://forecast.pacific.edu/desp-figs.html

3.1.3 Other Special Levees

While the Delta levees were originally constructed to protect agricultural lands and the small communities that developed primarily along the shipping routes up the Sacramento River, they now are critically important to preserving water quality, to through-Delta conveyance of water, and to the vast array of infrastructure that criss-cross the Delta. The islands that are critical to these functions are discussed and illustrated in Appendix D. It may be seen in Appendix D that most, if not all, islands are also critical to something else besides agriculture and the Legacy Communities. It should also be noted that the mapping of infrastructure in Appendix D is taken from DRMS and is not necessarily complete. For security and other reasons, some data such as the location of liquid fuel pipelines and fiber-optic cables are closely heldand are not included on publically available maps. Urban infrastructure in the Secondary Zone is also not shown.

3.1.4 Summary and Discussion

As may be seen in Table 1, just under 1,000 miles of levees are currently being maintained within the Legal Delta. But of these, 443 miles are either project or urban levees.If these levees are subtracted from the total of 980 miles, there are only 537 miles that need to be maintained and perhaps improved primarily by the State and the reclamation districts. The DWR draft Technical Memorandum (2011) makes a distinction between non-project levees that have special status in the California Water Code and are eligible for State assistance and other levees that might be owned by public agencies or private entities that are not eligible for State assistance. The technical memorandum indicates that those levees eligible for State assistance are shown on page 38 of the Delta Atlas.[23]

If urban areas and levees that are primarily flood-control levees in the north and south Delta are excluded from the total count, there are only 613 miles of “lowland” levees which protect lands below sea level. These are levees that are largely founded on peat and thus surround lands that have subsided. They are identified in Figure 10 by yellow dotted lines that are superimposed on either the black or red lines. Of these lowland levees, 143 miles are project levees, primarily located along the Sacramento River. That leaves approximately 470 miles of lowland levees that need to be maintained and enhanced primarily by the State and the local reclamation districts. Even this number errs on the high side because we have counted levee miles by island or tract and some islands or tracts that we have included in the “lowland” count, like Roberts Island for instance, have substantial areas above sea level. Thus, not all lowland levees are equally important but their definition is a significant step in prioritizing the relative importance of the various Delta levees. The 470-mile length might also be reduced by combining some of the existing islands and tracts into larger polders. Of this sub-set of the lowland levees, over 100 miles already exceed the PL 84-99 standard that is discussed below, leaving perhaps 350 miles in need of improvement to the PL 84-99 standard.[24]While the project and urban levees may have issues with encroachments, penetrations, and vegetation and otherwise be in need of improvement, there are other mechanisms for dealing with these issues, and the project and urban levees are fundamentally flood-control levees rather than levees that are key to protecting water quality, the conveyance of water through the Delta, and protecting and enhancing the Delta as a place.

[23]http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm

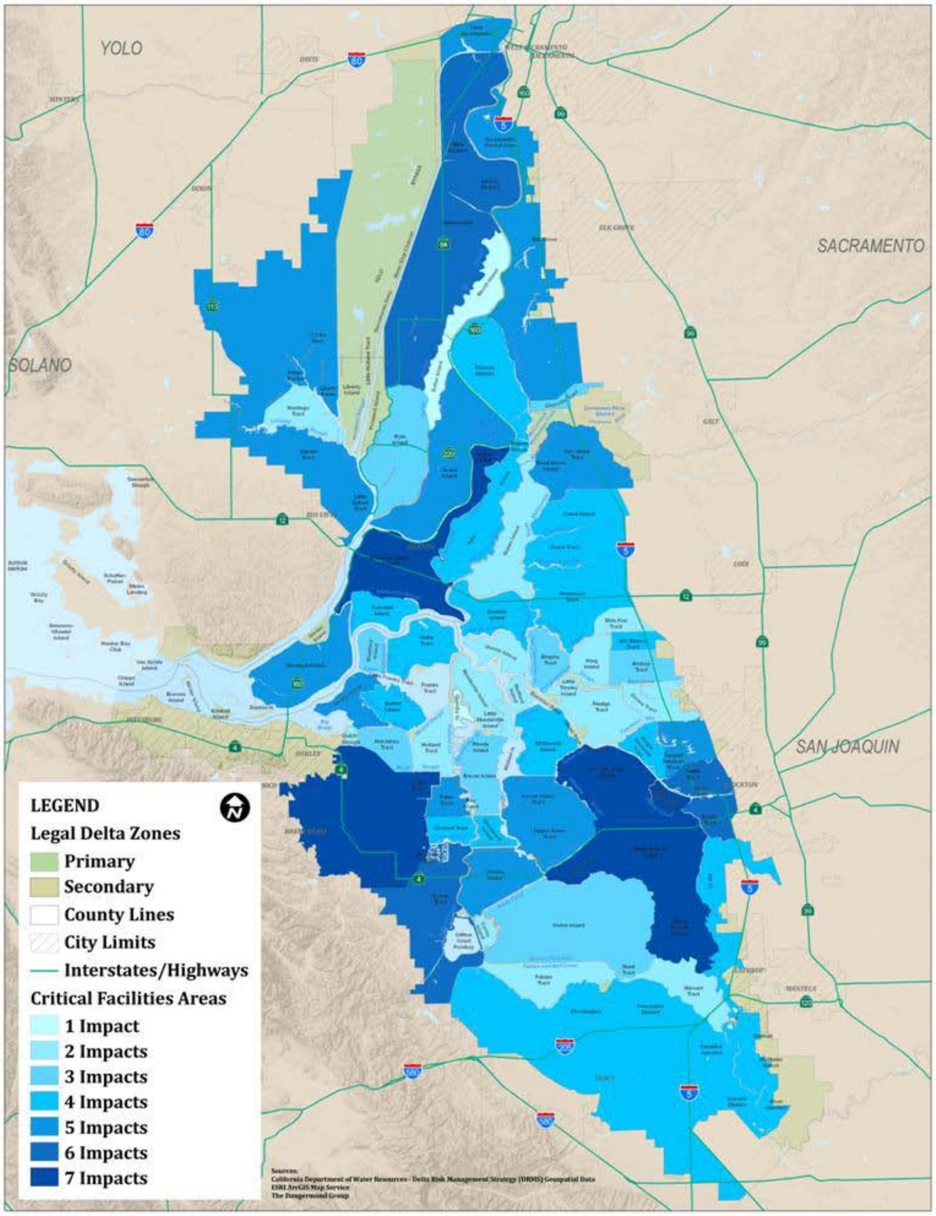
[24]Based on discussions with reclamation district engineers. These estimates will be refined and formalized in the 5-year plans that are now required as a prerequisite for state funding but the preparation of these 5-year plans has been delayed by delays in releasing the funding to develop them.

The definition of certain levees in Table 1 as “lowland” levees is not exact and at present has no legal significance. Most of the levees that have been called out as lowland levees are in the Primary Zone, although Bethel Island and Hotchkiss Tract have been included because they are two of the eight western island and tracts that are judged to be critical for preventing salinity intrusion; Wright-Elwood Tract also has been included because of its importance in protecting already urbanized areas to the east. The definition of these lowland levees is very useful for planning purposes because it is the islands that have significant land areas below sea level that are most exposed to the increasing risk posed by possible sea-level rise and that also serve to prevent salinity intrusion. Unlike islands and tracts where the land surface is above sea level, these islands cannot be drained naturally and have to be pumped out after first repairing the levee. Further, failure and flooding of even one of these islands potentially increases both the wave action and the seepage forces on the adjacent islands so that if the island is not repaired and drained promptly, progressive failure of additional islands may occur. Clear evidence of the effect of a single flooded island on adjacent islands was provided by the fact that levee integrity on Woodward and Victoria Islands was compromised by the failure and flooding of Upper Jones Tract in 2004.[25] Thus, the maintenance and improvement of the lowland levees are critical to the achievement of the coequal goals set forth in the Delta Reform Act of 2009. The concept of defining lowland levees is similar in purpose to the designation in the 2008 PPIC report[26] of 34 islands as core or significant islands.

All of the islands shown in Appendix D, which have levees protecting infrastructure or critical facilities of one form or another, are superimposed in Figure 16. Figure 16 is not necessarily complete and does not attempt to weight the relative value of the various kinds of infrastructure, but it illustrates the widespread distribution of significant infrastructure in the Delta and shows that most, if not all, islands or tracts house significant infrastructure or border important shipping or conveyance pathways.

[25]Neudeck,Christopher, KSN, Inc., personal communication.
[26]Lund, J., et al.,*Comparing Futures for the Sacramento-San Joaquin Delta*, Public Policy Institute of California, San Francisco, CA, August 2008.

Figure 7 All Islands Containing Critical Facilities[27]



[27] For high resolution image see http://forecast.pacific.edu/desp-figs.html

3.2 Levee Standards

A detailed discussion of the various standards that might apply to Delta levees was given by Betchart (2008).[28]Betchart's list can be simplified into the five standards listed below. Because the Delta is a unique place with unique soil conditions, some levee standards that are applicable elsewhere are not applicable in the Delta. These unique considerations are discussed in Appendix E.

Hazard Mitigation Plan (HMP)

The Hazard Mitigation Plan (HMP)"standard" is not an engineering standard but is a simple geometric levee description that was devised by FEMA in order to establish minimum requirements for federal disaster relief. It provides for a 16-foot crown width, a 1-foot freeboard above the 100-year water surface elevation, minimum 1.5-to-1 waterside slopes, and minimum 2-to-1 landslides slopes. Most existing Delta levees generally meet this standard, but because Delta levees built of or over peat are subject to on-going settlement, there is continuing argument over how literally this standard should be interpreted. The current regulatory position is stated in a MOU signed in February 2010 between Cal EMA and FEMA, as discussed by Betchart (2011).[29] However, notwithstanding its importance to disaster-relief funding, no engineer familiar with the Delta considers the HMP geometry to be adequate for even basic flood protection, and the reclamation districts are generally working towards full compliance with the higher PL 84-99 standard. While there are some miles of levees that, pending further improvement, waver around the HMP geometry, there are at present only about 50 miles that fall below HMP,[30] and even those levees fall short only by about a foot of elevation. As noted in the DWR Technical Memorandum, while achieving the HMP geometry is not really a goal from an engineering perspective, consistently meeting it is not only a first step towards the real short-term goal, which is PL 84-99, but is also important from the point of view of the State in maximizing federal assistance following any disaster.

While levee standards are generally thought of in engineering terms and vegetation on levees is discouraged, the treatment of levee vegetation is critical in the Delta (and elsewhere in California) where preservation or restoration of riparian habitat is an important goal. Vegetation management guidelines for local, non-project Delta levees that were adopted in 1994 require that the crown and the landside slope and a ten-foot strip along the landside toe must be cleared of visually obstructive vegetation,although mature trees may be retained. All vegetation except for grasses must be removed from the top five feet of the waterside slope. The guidelines suggest that naturally growing vegetation below the cleared area should be pruned or removed only to the extent necessary to insure levee safety and ease of inspection.

Public Law (PL) 84-99

Among other actions, Public Law 84-99 allows the Corps of Engineers to rehabilitate flood protection systems during a disaster. In order to qualify, the flood system must have already been enrolled into the Corps' Rehabilitation and Inspection Program. In 1987, the Sacramento District of USACE established a Delta-specific standard for levees, based on the Bulletin 192-82 joint DWR-USACE study that is described below, but with the requirement for 1.5 feet of freeboard reduced to being over the 100-year water surface elevation rather than the 300-year water surface elevation. Within the legal Delta this standard plus various maintenance and

[28]Betchart, W., Delta Levees – Types, Uses and Policy Options, Prepared for Delta Vision, August 2008.
[29]Betchart, W., Memo to Delta Levees and Habitat Advisory Committee with attached MOU, 2011.
[30]Based on discussions with reclamation district engineers. See previous footnote regarding the development of 5-year plans.

inspection requirements must be met in order to qualify for rehabilitation under PL 84-99. The Corps was careful to note that “the recommended guidelines are Delta-Specific and they are not intended to establish design standards for the 537 miles of non-federal levees in the Sacramento-San Joaquin Legal Delta, but to provide uniform procedures to be used by the Corps of Engineers in determining eligibility under PL 84-99, as amended.” In the preceding Bulletin 192-82 study it had been stated that “while the Corps’ design has accounted for small earthquakes, the lack of actual experience of the impacts of earthquakes on Delta soils leaves some doubt that levees, even after rehabilitation, could withstand an earthquake of Richter magnitude 5 or greater if the epicenter occurred in the Delta, or of magnitude 8 on the San Andreas or Hayward faults.” Thus, earthquakes were considered but not fully accounted for.

While sometimes referred to as the PL 84-99 Ag standard, this standard actually applies to both agricultural and urban levees within the Legal Delta. The standard adds a stability requirement to what is otherwise principally a geometric standard. It provides for a crown width of 16 feet, freeboard of 1.5 feet over the 100-year water surface elevation, a minimum waterside slope of 2-to-1, and landside slopes that vary as a function of the depth of peat and the height of the levee such that the static factor of safety on slope stability is not less than 1.25. Very approximately, the landslide slope can be 2-to-1 for levee heights no greater than 5 feet, can be 3-to-1 for levee heights no greater than 10 feet, can be 4-to-1 for levee heights no greater than 20 feet, and has to be 5-to-1 for levee heights of 25 feet or greater. Alternately, the minimum factor of safety can be achieved by construction of a landside toe berm. While this standard only calls for a minimum crown width of 16 feet, some reclamation districts are already planning for or are constructing improved levees with a 22-foot crown width, adequate for a two-lane, sealed road. This allows for two-way traffic in emergency situations and is to be encouraged. While this standard does not fully address earthquake loadings, the flatter slopes and/or landslide berms that are required for levees built over peat means that they are fundamentally less likely to suffer major distress as a result of earthquake loadings. This Delta-specific standard leads to the result that levees in the western and central Delta which overlie peat are likely to be less susceptible to damage in earthquakes than levees in the north and south Delta, which both overlie more sandy soils and tend to be composed of sandy soils and thus are more susceptible to liquefaction. While the Delta-specific PL 84-99 standard includes no specific guidelines on vegetation, it is assumed that the Corps national standards on levee vegetation, which basically ban all significant vegetation on both land and watersides, apply unless a specific variance from those standards is obtained. This question is currently the subject of a significant debate between the State of California and USACE, with the State arguing for the positive engineering and environmental benefits of vegetation on the waterside slopes of levees. The State’s position is indicated by the proposed provisions for urban levees which are noted below.

Sacramento District (SPK)
While not directly applicable to Delta levees, the Geotechnical Levee Practice of the Sacramento District of USACE (designated SPK) has some relevance because it informs both the Urban and Non-Urban Levee Evaluation programs and the DWR Urban Levee Design Criteria that are presently being developed. This SPK Practice calls for a minimum crown width of 20 feet for main-line levees and minimum water and landside slopes of 3-to-1. Existing levees, with landside slopes as steep as 2-to-1, may be retained in rehabilitation projects if their historic performance has been satisfactory. This move to 3-to-1 slopes is driven by maintenance issues as much as slope stability and seepage issues. The practice also suggests minimum requirements for geotechnical investigations and analyses. Although it describes recommended standard practice, it also makes it clear (and this aspect is often overlooked) that the responsible engineers should use appropriate judgment as a function of site-specific conditions and experience.

Urban Levee Design Criteria (ULDC)
DWR was directed by SB 5 to develop appropriate standards for urban levees, and version four of the Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley was published in December 2010. These criteria are now being finalized as the Urban Levee Design Criteria which will eventually become a State regulation. The ULDC is generally consistent with the SPK Practice and has the same geometric requirements. However, the ULDC goes much further in defining required practice in a number of other areas including seismic loadings, encroachments, penetrations and vegetation. With regard to vegetation, the draft ULDC language generally prohibits vegetation in accordance with the USACE national policy but allows woody vegetation on portions of the waterside slope and riverbank or berm for a newly constructed levee if a specially-designed waterside planting berm is added or the levee section is otherwise widened. In the case of the repair or improvement of existing levees, the draft ULDC language allows trees and other vegetation to be preserved over the long term if they provide important or critical habitat or erosion protection, soil reinforcement or sediment recruitment. In order to mitigate possible adverse effects of roots, where feasible the overall width of the levee should be widened landward by at least 15 feet or an effective root or seepage barrier shall be installed within the upper 10–15 feet below the levee crown. For other levees with pre-existing vegetation, the UDLC requires inspection and thinning in accordance with the Central Valley Flood System Improvement Framework. It is suggested that these provisions are generally applicable to Delta levees.

Proposed Higher Delta Levees Standard
With the exception of the ULDC, which addresses design and/or quick repair of levees for 200-year return period earthquakes, none of the above standards explicitly address seismically-resistant design, or design for greater than 100-year water surface elevations and possible sea-level rise. The 1983 Delta Levees Investigation (see Section 3.3.1 below) did suggest that Delta levees should be designed for 300-year water surface elevations but that suggestion has not been included in subsequent standards or revisions. Although updated estimates of water surface elevations from the Central Valley Flood Protection Plan are still pending, it is commonly believed that water surface elevations in much of the Delta are strongly influenced by tides and that 300- or even 500-year water surface elevations are only a foot or two higher than 100-year elevations. Pyke (2011)[31] has suggested that an appropriate standard for the design of Delta levees might be to design for 500-year flood and earthquake loadings. Likely, adoption of the ULDC requirement for three feet of freeboard over the 100-year water surface elevation coupled with superior flood-fighting would effectively provide 500-year flood protection. Building to this standard and increasing the crown width to a minimum of 22 feet would increase the cost only marginallyover the cost of complying with the Delta-specific PL 84-99 standard and this “PL 84-99 plus” standard may be sufficient for many Delta levees long-term. If the levee in question does not contain or is not underlain by loose sands that are susceptible to liquefaction, these PL 84-99 plus levees should be considered to be seismically robust. However, in order to more fully address earthquake loadings, possible sea-level rise and to provide the option for adding vegetation on the water side of levees, a higher Delta levees standard is required. This standard should particularly be required of most of the lowland levees which face the biggest hazard due to possible sea-level rise and are also the most critical to salinity intrusion, but it might be selectively applied to other Delta levees.

[31]Pyke, R., Comments of the First Staff Draft of the Delta Plan, Delta Stewardship Council, February 2011, http://deltacouncil.ca.gov/public-comments/read/143?page=1

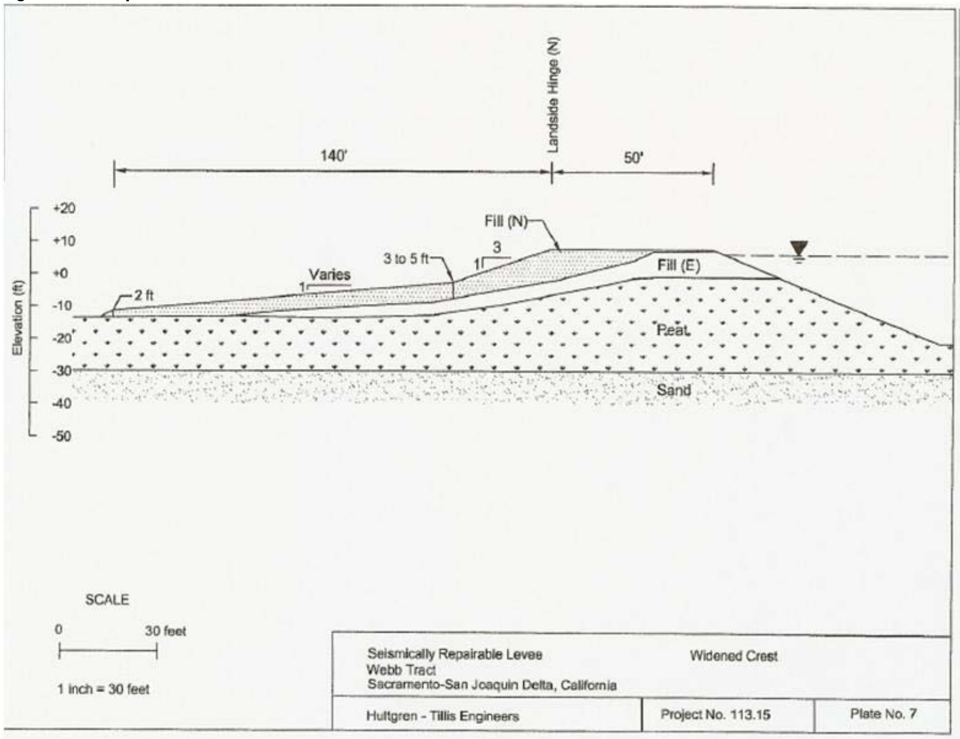
As an example of a levee with increased seismic resistance that also meets other objectives, the cross-section of a proposed seismically-resistant levee taken from a report by Hultgren-Tillis Engineers (HTE) for Reclamation District 2026 (Webb Tract)[32] is shown in Figure 17. Even when assuming that some liquefaction might occur both in the embankment and the foundation, this study indicates that deformations would be limited by the addition of a landslide buttress, as shown in the figure. A key feature of the design shown in Figure 17 is the wide crest. Wider crests not only provide a more robust levee, but also allow for more efficient emergency response. Levees with wider crests are also the most economical way to provide for possible sea-level rise. While it is the policy of the State to plan for 55 inches of sea-level rise by the year 2100, the probability of that magnitude of sea-level rise is actually very small. While it is not cost-effective or rational to construct levees to those elevations today, the provision of a wider crest today has two benefits: providing a more robust levee immediately, allowing more room for flood-fighting or emergency response following earthquakes, and allowing a choice of methods for raising the crest elevation in the event of actual sea-level rise. In addition, the provision of a wider crest also allows for retaining or planting vegetation on the waterside of the levee in accordance with the ULDC guidelines. Such planting should be an essential component of any comprehensive plan to repair the Delta ecosystem. Local widening of these levees would also allow for the construction of new recreational and tourist facilities out of the flood plain.

HTE estimated that this design would cost approximately $2 million per mile in 2009. HTE also looked at more elaborate designs which included either or both of a slurry trench wall or an internal drain. Those designs added up to $5 million per mile to the incremental cost but we believe that the additional features are not generally required and that an average cost of $2-3 million per mile is a reasonable estimate at this time. If it is assumed that anywhere from 300-600 miles of levees need to be upgraded to this standard, the basic engineering and construction cost would be in the order of $1-2 billion although the overall program cost might well be higher.

By comparison the 2007 PPIC report “Envisioning Futures”[33] listed in Table 8.2 an alternative labeled Fortress Delta (Dutch standards) which had a total cost greater than $4 billion and in Appendix E it is explained that was based on an estimated cost of $10 million per mile, applied to 300 to 500 miles of levees. The $10 million per mile figure was obtained by taking a $5 million per mile figure based on “recent informal estimates by water managers … including significant structural work” and doubling it because “Dutch levels of levee protection … would probably involve changes in many islands and channels, straining current construction and levee material capacity”. If it is assumed that “structural work” means including a slurry trench wall or internal drain then the $5 million per mile estimate is not inconsistent with the HTE estimates and these measures are in fact likely to be required to obtain “Dutch levels of levee protection” since currently Dutch levees are variously designed for 2,500 to 10,000 year levels of protection. However, the societal and economic considerations in the Netherlands are even more demanding than those in the Delta and we believe that a lesser upgrade to something like a 500 or 1000-year level of protection is appropriate for the Delta

[32]Hultgren-Tillis Engineers, Geotechnical Evaluation, Seismically Repairable Levee, Webb Tract, Report to Reclamation District 2026, December 2009.
[33]Lund, J., et al.,*Envisioning Futures for the Sacramento-San Joaquin Delta*, Public Policy Institute of California, San Francisco, CA, 2007.

Figure 8 Example Delta Levee Cross Section



3.3 Previous Studies of Delta Levees

3.3.1 Delta Levees Investigation, DWR Bulletin 192-82

In 1976 the legislature directed DWR to prepare a plan for the preservation of the Delta levees. After a joint study with USACE, a definitive plan for the improvement of all Delta levees was completed six years later and published as Bulletin 192-82,[34] which recommended a levee standard similar to the current Delta-specific PL 84-99 standard but with a requirement for 1.5 feet of freeboard over the 300-year water surface elevation. The forward to the report, signed by Ronald Robie, then Director of DWR, states in part:

> *Now is the time for a decision. The most significant element in a decision on what action to take is how much can we afford and who will pay? These questions can only be answered by the Legislature, the local landowners, and the Congress.*
>
> *There is a danger that taking a short-term view of Delta flooding problems will merely pass the tough issues on to the next generation. Short-run economic decisions may serve to subsidize private interest as the expense of the general public. The great challenge for the*

[34] Delta Levees Investigation, Department of Water Resources, Bulletin 192-82, December 1982.

Delta is to find an equitable way of financing a very uncertain long-term future. The political process is the traditional arena for handling these kinds of issues and is the right forum for the next step in Delta deliberations.

These policy issues must be addressed today. In the event the Legislature determines that a major responsibility for levee restoration should fall upon the State, a bond issue or other form of capital financing must be developed and approved by the people.

At that time, it was estimated that improving all levees to the proposed Bulletin 192-82 standard would cost $930 million if implemented immediately. However, although funding of the subventions program continued at a relatively low level, financing was never put in place to implement this more significant levee-improvement plan.

3.3.2 CALFED Levee System Integrity Program

A similar study, called the CALFED Levee System Integrity Program, was subsequently conducted as part of the CALFED program.[35] The executive summary of the Levee System Integrity Program Plan, dated July 2000, contains the following statements:

> *The benefits of an improved Delta Levee system include greater protection to the Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and conveyance benefits. The wide range of beneficiaries of the Delta Levee System Integrity program include Delta local agencies; landowners; farmers; boaters; wildlife; and operators of railroads, state highway, utilities, and water distribution facilities. Delta Water users and exporters also benefit from increased protection to water quality. Federal interests benefit from improvements to conveyance, navigation, commerce, and the environment, and from reduced flood damage.*
>
> *Recognizing these potential benefits, state and local agencies formed a partnership to reconstruct Delta levees. This effort has resulted in a steady improvement in the Delta levee system. The success of the Delta in the 1997 and 1998 flood events illustrates the value of the approximately $100 million of improvements made with SB 34 funds and over $10 million in emergency PL 84-99 work performed for the U.S. Army Corps of Engineers. These funds, in addition to local funds, have resulted in over $160 million in improvements to Delta levees since the SB program's inception in 1988.*

However, the summary continues with:

> *Many Delta levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect. As mandated by the California State legislature and adopted by CALFED, the physical characteristics of the Delta should be preserved essentially in their present form. This is necessary to protect the beneficial uses of the Delta. The key to preserving the Delta's physical characteristics and to achieving CALFED's objectives is the levee system. Over the next 30 years CALFED will invest billions of dollars in the Delta. The levees must protect this investment.*
>
> *The existing levee program (*the subventions program*) was intended to improve Delta levees up to the California/Federal Emergency Management Agency (FEMA) Hazard Mitigation Plan (HMP) Standard. As of January 1998, 36 of 62 (58%) Delta islands and*

[35] Op. cit.

tracts were in compliance with the HMP standard. This has resulted in a significant improvement in the ability to protect the beneficial uses of the Delta. However, as CALFED invests in the Delta, more is at risk. Therefore CALFED has chosen to improve the Delta levees to a higher level.

The CALFED Levee program will institute a program that is cost-shared among the beneficial users to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this standard are eligible for federal emergency assistance under PL 84-99.

The plan to improve the levees to the PL 84-99 standard was not new. It had been recommended in Bulletin 192-82. The CALFED study estimated that the cost of improving all the Delta levees to the PL 84-99 standard ranged from $367 million to $1.051 billion, not inconsistent with the $930 million estimated in 1982. But again, no funding materialized until in 2006, in the wake of the Paterno Decision, Propositions 84 and 1E provided for up to $615 million to be spent on Delta levees.[36] The slow pace of disbursement of these funds is discussed subsequently but, in effect, this was the funding that had been recommended first by Bulletin 182-92 and then by CALFED.

The CALFED plan also discussed the fact that funding for levee work is insufficient, inconsistent, and often delayed; that dredging is required to increase channel capacity and to provide material for levee reconstruction, habitat restoration and creation, and subsidence control, but that dredging had been curtailed due to regulatory constraints, causing dredging equipment and trained manpower to leave the Delta; that emergency response capabilities need to be continuously refined and funding increased; that levee reconstruction and maintenance sometimes conflicts with management of terrestrial and aquatic habitat resources; that obtaining permits for levee work can sometimes be difficult and time consuming; and that while subsidence may adversely affect levee integrity, this can be corrected.

With respect to seismic loadings, the plan said:

Some CALFED stakeholders are concerned that earthquakes may pose a catastrophic threat to Delta levees, that seismic forces could cause multiple levee failures in a short time, and that such a catastrophe could overwhelm the current emergency response system.

CALFED agrees that earthquakes pose a potential threat. In addition, Delta levees are at risk from floods, seepage, subsidence, and other threats. To address this concern, CALFED has begun a risk assessment to quantify these risks and to develop a risk management strategy.

The plan listed 10 possible risk management options which included improving emergency response capabilities and reducing the fragility of the levees and indicated that the final Risk Management Plan might include a combination of the 10 options. CALFED never completed the Risk Management Plan, and the effort evolved into the Department of Water Resources' Delta Risk Management Strategy.

[36]Some sources indicate that $775 million was intended to be spent on Delta levees but the draft DWR Technical memorandum indicates that only $615 million was made available by these propositions.

3.3.3 Delta Risk Management Strategy

AB 1200 (authored by John Laird, the current California Secretary for Natural Resources) required that DWR evaluate the potential impacts on water supplies derived from the Delta based on 50-,100-, and 200-year projections for each of the following possible impacts: subsidence, earthquakes, floods, climate change and sea-level rise, or a combination of these impacts. This legislation had the effect of changing the CALFED recommended study into what became the Delta Risk Management Strategy (DRMS) and the Risk Management Plan envisioned by CALFED has never been completed.

DRMS was conducted for the Department of Water Resources (DWR) by a team of consultants led by URS Corporation and Jack R. Benjamin & Associates.[37] The study was designed to have two phases. The first phase was an assessment of the then-current (2005) risks to the Delta and the second phase was to have been a projection of future risks assuming various scenarios. The Phase One draft generated a great volume of critical comments, and the effort required to respond to them cut into the available funding for Phase 2. The Phase 1 Risk Analysis Report was released in 2009, but the report on the modified Phase 2 study has only just been released.

Although led by very competent principal investigators, the DRMS effort was always hampered by being schedule-driven rather than quality driven. The DRMS Phase One report was extensively reviewed, including a review by an independent review panel (IRP) assembled by the Cal-Fed Science Program. The reviews were generally critical of the study. After revisions had been made, the IRP review[38] concluded that "the revised DRMS Phase 1 report is now appropriate for use in DRMS Phase 2 and serves as a useful tool to inform policymakers and others concerning possible resource allocations and strategies for addressing risks in the Delta." But the IRP expressed concerns:

> "*This conclusion, however, is subject to some important caveats. First, the IRP cautions users of this revised DRMS Phase 1 report that future estimates of consequences must be viewed as projections that can provide relative indicators of directions of effects, not predictions to be interpreted literally. Second, anyone using the results of the DRMS scenarios must be aware that ecosystem effects are not fully captured in the analysis....*"

Although the DRMS developed a good framework for assessing risks to the Delta levees, the effort had data gaps that were never filled, as acknowledged in the note on page 1-1 of the report. Gaps such of these in data and knowledge tend to drive the estimates of fragilities down, and the risks up. However, despite the warning from the IRP, the numerical results from the DRMS Phase 1 report are widely quoted and used in other studies, painting a more pessimistic picture of the Delta levee system than is warranted. Just one example of the questionable results is presented by the last map in the DRMS Executive Summary depicting a high probability of flooding for Sargent-Barnhart Tract, which houses Stockton's most expensive neighborhood, known as Brookside. This tract has had modern levees that meet 200-year urban standards and is shown as having a mean annual probability of failure of greater than 7 percent, while the adjacent Wright-Elmwood Tract, which is undeveloped and has relatively poorer levees, is shown as having a mean annual probability of failure of only 1-3 percent. In addition, recent improvements have been made to many urban levees in addition to recent and on-going

[37] http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/

[38] The independent review panel (IRP) comments on the DRMS Phase I draft report are published on the State's archived CALFED website: http://calwater.ca.gov/science/drms/drms_irp.html.

improvements to non-urban levees under the Delta levees subventions and special projects programsand these improvements are not reflected in the DRMS Phase 1 assessment.

The DRMS Phase 2 study focuses on risk reduction as opposed to risk analysis and evaluates the costs and benefits of four alternative scenarios for levee improvement and conveyance. Although Phase 2 was not released until June 2011, the forward to the report notes that it was completed in 2009, which explains why it utilizes costs for isolated conveyance that are less than half more current cost estimates. Like Phase 1, Phase 2 did not include acquisition of updated data. The report states:

> *Similar to the Delta Risk Management Strategy (DRMS) Phase 1 Risk Analysis Report(URS/JBA 2007h), the DRMS Phase 2 Risk Reduction Report was carried out for the most partusing existing information (data and analyses). The Phase 2 schedule did not afford theopportunity to conduct field studies, laboratory tests, or research investigations.*

Section 20 of the report lists a number of assumptions and limitations, and concludes:

> *The complexity of the issues in the Delta and the limited time available to undertake thePhase 2 effort means that additional scenarios that could not be developed in this phase willrequire consideration. Further, the performance of sensitivity analyses of the scenariosthemselves would be valuable to assess the importance of the major components of thescenarios on the overall risk reduction benefits. Other ongoing agency initiatives will likelyrequire consideration of additional scenarios.*

While these limitations and the awkward construction of scenarios discussed below make the final conclusions of the Phase 2 report unreliable, the DRMS phase 2 report is still a wealth of detailed information regarding individual components of the scenarios. In fact, the key findings relative to the two types of levee upgrades that were considered (and are listed below) are not inconsistent with the present study.

- *Most of the Delta levees already meet the HMP standard.*
- *Some of the levees in the central Delta (project levees) already meet the PL 84-99 standards.*
- *The cost of upgrading 764 miles of selected non-project levees (levees that do not meet PL 84-99 standards) in the central Delta to PL 84-99 standards is about $1.2 billion.*
- *The cost of upgrading 187 miles of selected levees around urban centers to UPL standards is $750 million.*
- *Upgrading levees to meet the target standards will reduce the probability of failure due to flooding. However, these upgrades do not guarantee that the upgraded levees, particularly those upgraded to PL 84-99 standards, will not fail during a 100-year flood. The 1.5 feet of freeboard is insufficient for regions subject to high winds during floods.*
- *Upgrading levees to meet the PL 84-99 and UPL standards does not reduce the seismic risk of levee failure.*

Elsewhere the report says that "upgrading the levees to the Pl 84-99 and UPL standards would <u>do little</u> to reduce the risk of failure under seismic loading." However, curiously, the report says nothing about what it would take to further upgrade the critical levees so that they are more robust under seismic loadings.

Rather Scenario 1, which is entitled “Improved Levees,” assumes that the levees are not robust under seismic loadings and estimates the cost of hardening the state highways that cross the Delta, by putting them on piles like the elevated section of the Yolo Causeway, and the BNSF railway and the Mokelumne Aqueducts, either by building seismically-resistant embankments with a 50-foot crown width on either side of the existing railway and aqueducts, or by placing the railway and aqueducts on a single embankment with a 180-foot crown width. The cost of these hardening measures was estimated to be $6.1 billion for the highways and $3.3-3.9 billion for the infrastructure corridor. Adding these figures to the cost of the planned levee improvements resulted in a stated total capital cost for Scenario 1 of $10.4 billion, as reported in Table 1 of the executive summary. Thus, the “Improved Levees” scenario isnot a broad improvement of Delta levees as described in this report, but has 60 percent of the total cost allocated to putting a few state highways on piers, a strategy that the report notes does not generate benefits equal to the costs and creates numerous problems for the network of local Delta roads. It should be titled an “elevated highways” scenario since that is its most prominent feature, as highways do not have to be elevated for the type of improved levees strategy described in the ESP.

Likewise Scenario 2, which is titled “Through Delta Conveyance (Armored Pathway),” ignores the possibility of a general upgrade to levees that are more robust under seismic loading and instead assumes the construction of 115 miles of new seismically-resistant setback levees, at a cost of $38 million per mile. The total capital cost of the scenario is $15.6 billion, because this strategy is also paired with $5 billion in costs to put roads on piers.

Scenarios 3 and 4 examine isolated and dual conveyance, and greatly misrepresent the costs of these strategies as being comparable to or cheaper than through Delta conveyance strategies. First, they utilize out-of-date costs for isolated conveyance that are under $5 billion compared to current estimates of $12 billion or more. Second, these scenarios also reduce cost by not including the $3.3 billion armored infrastructure corridor included in Scenarios 1 and 2. As a result, the costs and composition of the four illustrative scenarios are constructed in such a way that the final conclusions are of little value.

This study concludes that most lowland Delta levees and selected other levees can be made robust under seismic loadings for a base engineering and construction cost of $1-2 billion. Even if the total program cost were $4 billion as suggested by PPIC (2007), a true “improved levees” scenario would have much lower costs than the version in DRMS and would perform much better in reducing the costs of in-Delta flood losses as well as out-of-Delta losses from water supply reliability and therefore have higher benefits. Although it is impossible to draw conclusions without a complete analysis, a true “improved levees” scenario would likely have a much higher benefit-cost ratio than the other scenarios considered in DRMS phase 2.

3.3.4 Delta Islands and Levees Feasibility Study

Meanwhile, the successor to the Bulletin 192-82 and CALFED studies is the USACE Delta Islands and Levees Feasibility Study, which is an on-going effort in collaboration with DWR.[39] The official description of the study is:

> *Thisfeasibilitystudy is USACE’s mechanism to participate in a cost-sharedsolutiontoavarietyofwaterresourcesneedsforwhichwehavetheauthority. Resultsofstateplanningeffortswillbeusedtohelpdefineproblems,opportunities,andspecificplanningobjectives. The feasibility study will address*

[39]http://www.spk.usace.army.mil/projects/civil/Delta/News.html

ecosystemrestorationandfloodriskmanagement,andmayalso investigaterelatedissuessuchaswaterqualityandwatersupply. USACEandDWRsignedaFeasibilityCostSharingAgreement(FCSA)inMay2006.

The initial public findings and outreach are not expected until later this year. Thus, three joint State-Federal efforts over the last 30 years have had significant positive impact in that they have generated the concept of improving Delta levees to the PL 84-99 standard and have supported the continuation of the funding that is provided under the subventions program and the additional funding that was authorized under Propositions 84 and 1E and the CALFED Levee Stability program. However, they have not yet led to a strategy which will make the Delta sustainable longer-term facing the hazards due to floods, earthquakes, and possible sea-level rise.

4 RiskReduction Strategies

There are three basic approaches to addressing the risks posed to the Delta levees by floods and earthquakes. One is to simply make the up-front investment to improve the existing levees so that they are more robust; a second is to make the preparations in advance for improved flood-fighting and/or emergency repairs following an earthquake so that breaches do not occur; the third is to make preparations in advance for repair of breaches and the draining of any flooded islands if breaches do occur so that the consequences are minimized. These three approaches are discussed in more detail in the following sections, and is followed by a discussion of economic justification for investing in risk reduction strategies.

4.1 Improve the robustness of the existing levees

This is the standard approach to reducing risk:invest up-front in making everything more robust. As discussed earlier, a series of reports over three decades have concluded that Delta levees should be improved to the Delta-specific PL 84-99 standard. However, the Department of Water Resources has released a draft “Framework for DWR Investments in Delta Integrated Flood Management,”[40] a document that was only released for public comment on July 15, 2011, but had already been forwarded to the Delta Stewardship Council,that states or implies that the HMP “standard” provides an adequate basic level of protection against floods and earthquakes for Delta levees. The exact language of the draft Framework is:

> *As funding is available, DWR intends to cooperate with local public agencies to develop local plans to improve levees within the Delta levee network to at least the HMP standard. Some levees may warrant additional investment to provide a level of protection beyond the HMP standard, but these projects likely would need to be justified based on one of the other categories of benefit described in this section.*

Apparently on the basis of this language, the 5th staff draft of the Delta Plan, in Table 7-1, indicates that levees built only to the HMP “standard” are acceptable for protection of agricultural lands. However, the HMP “standard” is not an engineering standard. It is a minimum configuration agreed to by the state and federal governments for the purpose of defining a serious levee in order to protect the federal government from facing possible exposure to the cost of repairing levees that are height limited or not seriously being maintained. Since 1982, the minimum standard for engineered levees in the Delta has been the Delta-specific standard

[40] California Department of Water Resources, DRAFT V3 DHF and SMB, “A Framework for Department of Water Resources Investments in Delta Integrated Flood Management,” February 14, 2011.

that was recommended in Bulletin 192-82 and subsequently adopted by the Corps of Engineers as the PL 84-99 standard for Delta levees. This Delta-specific PL 84-99 standard was also adopted in the CALFED Levee System Integrity Program Plan as the minimum standard for Delta levees. That plan specifically said:

> *The CALFED Levee program will institute a program that is cost-shared among the beneficial users to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this standard are eligible for federal emergency assistance under PL 84-99*.

The draft Framework and the draft Delta Plan would roll back 30 years of joint state-federal co-operation without sufficient justification. The draft Framework is inconsistent with DWR's own draft Technical Memorandum (2011) that is cited in the Framework document, not to mention CALFED and Bulletin 192-82. Given that it is possible, even likely, that FEMA will raise the minimum levee standard required for reimbursement after a disaster from the HMP standard to the PL 84-99 or some higher standard, the proposed policy change means the state would be forgoing the opportunity for significant federal financial assistance to sustain and enhance the Delta. As discussed in more detail below in section 4.4, the call in the draft Framework for economic justification for improvements to levees from HMP to PL 84-99 standards can be economically justified for most, and possibly all, Delta levees. Thus, implementing the DWR Framework could delay necessary investments and increase administrative costs that reduce available resources and increase risk.

In stark contrast to the DWR proposal for a lower Delta levee standard, this Plan argues that many Delta levees should be improved beyond PL 84-99 levels to a higher Delta levee standard described in section 3.2. The argument for making this additional investment is pretty straight-forward: even the Delta-specific PL 84-99 standard does not provide adequate protection from more extreme floods and earthquakes and does not provide a basis for adaption should sea level rise at an enhanced rate. Assuming a cost of $2–3 million per mile for 300 to 600 miles of levees, the $1–2 billion minimum investment that would be required to improve most lowland levees and selected other levees to this higher standard is small compared to the value of the land that they protect, the recreational benefits that they provide, the value of the infrastructure that crosses the Delta, and the increased reliability of water conveyance through the Delta. Furthermore, the cost is substantially lower than improving water supply reliability with isolated conveyance.

4.2 Improve both inspections and emergency preparedness and response to prevent failures

As discussed above and in Appendix E, few if any levee failures actually occur without warning. There is normally a few days to a few weeks warning of flood events. Earthquakes occur without warning, but the consequences of even a moderate-to-large earthquake that affects the Delta are more likely to be some slumping rather than immediate breaches. Even sunny-day failures may be preceded by signs of trouble. Since levee failures typically come after days or weeks of initial warnings, it is clearly cost-effective to invest in emergency preparedness and modern investigative techniques to head off failures before they occur.

Below are some of the measures that might improve this kind of emergency preparedness.

- Create stockpiles of the newer types of temporary means for raising levees such as

“Aquatubes” or “Aquafences.”These allow for temporary increases in the levee height when a particularly severe flood threatens or after an earthquake. These devices can quickly raise the crest of a levee over much greater lengths than can be accomplished with conventional sandbags.

- Create stockpiles of appropriate materials to deal with enhanced seepage and develop the means to transport them quickly to any point in the Delta.
- Set in place plans and procedures for emergency repairs to levees following an earthquake. This might include borrowing from landside toe-berms as suggested above.
- Use newer technology, such as that developed at the University of Texas at Austin by Professor Kenneth Stokoe for monitoring highway and airfield pavements, to conduct periodic inspections of the levees. This technique senses small changes in the levee, such as those caused by rodent burrowing, and thus flags locations that require more detailed inspection.
- Install simple fiber-optic cables at the toes of levees as suggest by Professor Jason de Jong of UC Davis in order to sense deformations. Again, this technique flags locations that require more detailed inspection and, in the event of an earthquake or terrorist activity, would immediately identify trouble spots for emergency managers and national security personnel.

Improved federal, state, county, and community coordination is equally important in preventing failures. Notwithstanding improvements in coordination that are currently being worked on, the suggestion made elsewhere that responsibility for emergency-response planning be turned over to a Delta-region authority with an appropriate funding base appears to have great merit.

4.3 Improve both immediate response and longer-term recovery after failures

In general, emergency response following a breach involves two elements. The first of these is very immediate and involves controlling the spread of flood waters, evacuating threatened people and livestock, and minimizing damage. In the riverine environment this might involve blocking freeway underpasses or otherwise reinforcing secondary levees and making relief cuts through levees to drain floodwaters back into the river system at a lower point on the river. To be effective, these actions require detailed emergency planning and preparation. However, while this kind of planning and preparation should be made for the Delta islands, there is likely little that can be done in this regard on most of the more deeply-subsided islands following a breach. It is difficult or impossible to reduce or stop the flow of water until the island is flooded and water levels equalize. Once that has happened, the breach can be repaired and the island pumped out. However, as illustrated by the repair of the 2004 Upper Jones Tract failure, unnecessary delays and expense can occur unless the repair of the breach is planned and executed properly. In that case larger rocks were used to initially plug the breach but there were insufficient fines to limit continuing seepage to an acceptable rate. That resulted in construction of a waterside berm with provision for the planting vegetation on a bench in part as mitigation for encroachment into the channel, as may be seen in Figure C7 in Appendix C. Thus forward planning and stockpiling of suitable materials for repair of levee breaches is very desirable. In the absence of a one-stop permitting mechanism, it also seems very desirable that this forward planning includes establishment of a fast-track procedure for acquiring any necessary permits or authorizations. Speedy repair of breaches and pumping out of flooded islands not only minimizes damage and losses on the island in question but also the losses that occur as a result of enhanced seepage into adjacent islands.

4.4 Current planning efforts

4.4.1 High-Level Coordination

In response to SB 27, the California Emergency Management Agency, Cal EMA, organized a Delta Multi-Hazard Coordination Task Force. Since funding was never provided by the legislature, this task force operated on limited funding to develop a draft report that recommends that $11.5 million be allocated for various planning studies and that a permanent emergency response fund of $50-150 millionbe established. Some of the recommended planning efforts appear to overlap with DWR-USACE activities that are already under way, but the final Task Force report has not yet been released.

4.4.2 DWR Emergency Planning

The current DWR studies were initiated by the Metropolitan Water District of Southern California (MWD) which, commencing in February 2006, undertook a study of two options for minimizing the interruption of exports resulting from a hypothetical 50 levee breaches/20 flooded islands scenario. The pre-event scenario involved advance construction of levee and river-flow barriers to block saltwater from entering the south Delta in a major emergency. It was estimated to cost $330-485 million. The post-event strategy allowed saltwater to enter the entire Delta, followed by the creation of an emergency freshwater pathway to the export pumps. The cost estimate for this strategy was about $50 million for pre-positioning of materials, with an ultimate cost of perhaps $200 million. MWD then elected in April 2007 to pursue the second alternative in association with the State Water Contractors and DWR using funds from propositions 84 and 1E to the maximum extent possible.

By January 2008 DWR was reporting on progress on the adopted strategy. At that time, contracts had been signed for the delivery of 240,000 tons of rock to three stockpiles in Rio Vista, Hood, and the Port of Stockton by June 2008. A planned second phase would have increased the quantity of rock at each location and added additional “breach closure materials.”

That work has now apparently been subsumed into the development of a broader program which is intended to guide DWR’s activities during an emergency.[41] This program includes three components:

1. Development of a plan for flood emergency preparedness response and recovery in the Delta. This plan consists of three elements:

    A. In association with USACE, development of a GIS-based flood contingency maps and associated data.

    B. Development of strategies for minimizing the delay in restoring fresh water to the export pumps. This includes advanced modeling of salinity intrusion and risk assessments. Although no results have been officially reported, it is understood that these studies suggest that the Delta flushes out more rapidly than had previously been expected, and that exports could be resumed in a maximum of six months, but more likely in a shorter period, even if multiple islands have been flooded. These studies are expected to produce tools that can be used to guide short-term water conveyance and upstream reservoir operations and prioritization of possible placement of emergency

[41]Delta Flood Emergency Preparedness, Response and Recovery Program, An Overview, DWR Brochure, June 2011, and presentation to Delta Stewardship Council, September 23, 2011.

rock barriers and levee repairs.

C. Definition of the roles and responsibilities of DWR emergency response personnel and coordination with other agencies.

2. Coordination and integration of DWR's plan with the plans of other Delta flood response agencies.

3. Development and implementation of flood emergency response facilities in the Delta. Implementation of this item requires additional legislation to allow redirection of bond funding for this purpose.

4.4.3 County-Level Planning

Work is continuing on various county emergency response plans but these are more oriented to immediate response and public safety than to repair of levee breaches and de-watering of flooded islands. Nonetheless, there are many elements of these plans, such as the flood maps and guide developed by San Joaquin County[42] that could be usefully extended to cover the entire Delta. However, rather than having individual county plans, it would seem to be desirable to have a single integrated Delta-wide emergency response plan that identifies only as sub-sets the actions that need to be taken by the individual counties.

Comment [RMP1]: This language was not intended to suggest that public safety is unimportant. Ratherit was intended to suggest that while it is appropriate that public safety be the primary concern of the county emergency reponse, it is not the only element of emergency preparation, response and recovery that needs to be addressed.

4.5 Discussion of Alternate Risk Reduction Strategies

In summary, while some progress is being made on all three approaches to risk reduction, much of the DWR effort appears to be directed to the third approach, responding to failures after they have happened, instead of preventing them. The current round of DWR studies should be certainly be completed, butgoing forward much more emphasis should be given to the issues raised by Baldwin (2011),[43] most notably that a regional emergency response agency is required, and that the regional emergency response agency should place much more emphasis on preparation for flood-fighting and emergency response following earthquakes, as discussed herein in Section 4.2.

4.6 Economics of Risk Reduction Strategies

Figure 16 indicates that there are few, if any, islands in the Delta that are in purely agricultural use. However, even the discussions of agricultural value focus only on property value or net profits to farmers, ignoring all the other income and economic activity created by farm employees, suppliers, and related enterprises. For many islands, the energy and transportation infrastructure, homes and businesses far exceed the agricultural value. Even if a flooded island were purely agricultural, permanent flooding would have adverse impacts on the levees of adjacent islands through wave action and enhanced seepage. In addition to the agricultural and infrastructure losses and stress on adjacent levees, though Delta conveyance of water is impacted in the short term, and if islands were to be left in a flooded condition, both in-Delta and out-of-Delta uses of water would be impacted by other water quality issues such as increases in

[42] http://sjmap.org/oesmg/gfcm/Flood_Map_Guide_Final_6-1-10.pdf
[43] Baldwin, R., San Joaquin County Comments on the First Staff Draft of the Delta Plan, 2011, http://deltacouncil.ca.gov/public-comments/read/143?page=1

organic carbon. As noted by both Healey and Mount (2007)[44]and Suddeth (2011),[45]the ecological benefits of additional flooded islands are uncertain, whereas many agricultural islands (particularly those with low-value crops that are said to be not worth saving) provide critical habitat to migrating birds along the Pacific flyway. According to the draft DWR Technical Memorandum, the Delta levees presently provide a home for as many as 500 species, including several rare and endangered species, in its current configuration. Thus, although the current Delta is not as productive and valuable an ecosystem as the historic Delta, it still has considerable ecological value. As discussed elsewhere in this report, creating large open water areas would impact recreation and tourism because most Delta boaters are attracted to the Delta for its meandering, wind-protected channels. Finally, flooded islands also have much higher evaporation rates than agricultural lands so that there is a net loss of water from the system.[46] The following is a summary list of the economic assets and values protected by Delta levees:

- Net farm profits (capitalized into farmland values)
- Residential and commercial structures
- Flood protection of nearby islands/levees (reduced flood-control costs)
- Critical infrastructure such as fuel pipelines, natural gas wells and storage, electricity transmission lines, highways and roads, railroads, deep-water shipping channels, communications infrastructure (TV/radio/phone towers)
- Other income generated by agriculture production (ripple effects)
- Water quality for municipal and industrial users in and outside the Delta
- Wildlife habitat
- Water conveyance
- Water supply (reduced freshwater consumption)
- Recreational values (primarily boating channels and hunting areas)
- Lost opportunity for future beneficial uses

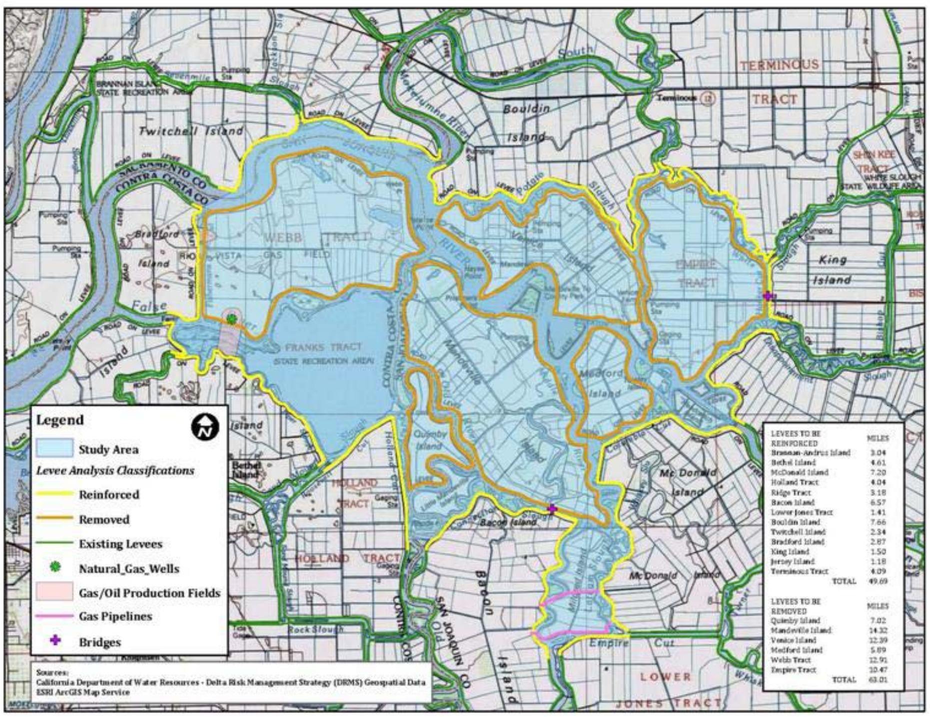
A good start on a more comprehensive assessment of the economics of levee upgrades, repairing breaches and draining flooded islands was made by Suddeth et al. (2008) and refined in Suddeth et al. (2010). In this very influential study, Suddeth et al. calculated the net expected costs for 34 subsided Delta islands and three scenarios: no upgrades from the 2005 conditions estimated by DRMS; upgrades to the Delta-specific PL 84-99 standard; and upgrades to that standard plus an additional 1 foot of freeboard. In addition to an estimate of agricultural land value for each island, the analysis included the value of structures on the islands. The analysis considered the estimated costs of repairing breaches and draining flooded islands and the costs of not repairing islands, which included the cost of rebuilding or re-locating roads and the cost of fortifying nearby islands, in order to make decisions on whether or not to recover flooded islands. In terms of the bullet list above, Suddeth et al. account for most of the first four value categories, but their model does not address the more difficult to measure impacts in the rest of the list.

In their initial analysis, Suddeth et al. find that it is not “economically optimal” to upgrade levees to the PL 84-99 standard, and only cost-effective to repair 18 to 23 of the 34 islands if they fail.

[44] Healey, M., and J. Mount, Delta Levees and Ecosystem Function, Memorandum to John Kirlin, Executive Director of Delta Vision, November 2007.
[45]Suddeth. R., Policy Implications of Permanently Flooded Islands in the Sacramento-San Joaquin Delta, UC Davis Center for Watershed Sciences, 2011,http://watershed.ucdavis.edu/pdf/.
[46]Sacramento Valley Water Use Survey 1977, DWR Bulletin 168, October 1978.

However, this result is very dependent on the assumed costs, values, and failure probabilities, and sensitivity analysis in the article show significant changes when assumptions are adjusted to more realistic values. For example, the initial analysis assumes most agricultural land is worth $2,500 per acre based on a simulation of net profits, when current appraisals for Delta farmland are $6,000 per acre and nearby cropland without Delta flood risk is valued at $10-12,000 per acre. In addition, estimated probabilities of levee failure were taken from DRMS which a previous section explains are thought to err significantly on the conservative side. While the cost estimates that were used for levee upgrades to PL 84-99 were reasonable, it was assumed that each upgrade only reduced the probability of failure by 10 percent. In contrast, DRMS phase 2 report estimated a 24 percent decline in failure probabilities from PL 84-99 upgrade, and improvements might well be even greater, especially if the levee system is upgraded to uniform compliance with the PL 84-99 standard. In addition, the estimated cost of reinforcing the surrounding islands (and thus limiting the propagation of failures) is low, and other costs associated with leaving islands flooded (including the adverse effects on recreation and water quality) were neglected.

Figure 9The Suddeth et al. (2010) Inland Sea[47]



Fortunately, the most recent version (2010) of the paper includes some much needed sensitivity analysis to the study assumptions. In the most interesting scenario, the authors tripled their

[47] For high resolution image see http://forecast.pacific.edu/desp-figs.html

assumed property values and “Do Not Repair” costs in what they call an “extreme case.” In our view, this scenario is not extreme at all, but uses far more accurate values for two key variables. The results show nine islands that are not repaired, including six contiguous islands in the Central Delta and three small islands scattered in other areas. The results are displayed in Figure 9 of Suddeth et al. and the six central Delta islands are displayed in Figure 18above.

These six islands in the Central Delta are the most likely candidates for conversion to open water, because they are relatively free of people, property and infrastructure and support mostly low-value crops. Thus, we have included this open water scenario as a policy scenario in subsequent chapters to more fully assess the potential effects to areas not considered by Suddeth et al. such as recreation and several categories of infrastructure. More details are found in subsequent chapters but we preview the results here to complete the present discussion.

The total length of the levees around the six islands is 63 miles, and the total length of the surrounding levees that would have to be improved to a higher standard to deal with higher wave heights and seepage is approximately 50 miles. If Webb Tract, which is one of the eight western islands called out for their importance to protecting against salinity intrusion, and Empire Tract, which houses the new City of Stockton water intake, were to be omitted from the list, the length of the levees removed would drop to 43 miles. The length of levees that would need to be improved, however, would only drop to approximately 45 miles. In our judgment, the cost of reinforcing the surrounding levees to cope with higher wave height and seepage forces would likely be much greater than the $1-2 million per mile cost of improving the levees on the existing islands, thus on the basis of the cost of improving and maintaining levees alone, the creation of this inland sea cannot be economically justified. But there are also additional factors that must be considered. First, Suddeth et al. did not account for major new water supply facilities for the City of Stockton that are being completed on Empire Tract. Accounting for this facility, Empire Tract would surely be excluded from the “do not repair” list, and the water quality problems from permanent flooding of nearby Medford, Venice, and Mandeville Islands would increase due to the nearby intake. Second, this open-water area is in the heart of the Delta’s most popular area for boating recreation and is surrounded by about half of the Delta’s marinas. The recreation experts on our study team, and numerous interviews with Delta recreationists unanimously agreed that this large open-water area would have a large negative effect on the Delta boating economy, for the boating attraction is the Delta’s unique meandering channels protected from wind and waves. Third, although these islands are free of major highways and railroads, almost all of them border the Stockton Deep-water Shipping Channel, and their permanent flooding would create several problems for the Port including the need for increased dredging that is already constrained by a tight time window for environmental reasons. As discussed in the infrastructure chapter, expanding the Port of Stockton is at the center of the region’s economic development, transportation, and air pollution reduction plans.

Taking into account these additional costs, Quimby Island is the only one of these six that might reasonably be considered for a “do not repair” list and eventual conversion to open water. Using this framework, the other three small islands that might be considered for “do not repair” status are Coney, Fay, and Dead Horse. The levee lengths on these islands range from 1.6 miles on Fay to 7 miles on Quimby for a grand total of 16.7 levee miles on the four candidate islands that may be expendable among the hundreds of miles of Delta levees. Even if upgrading and repairing these islands were not technically cost-effective, there would still be some benefits from the investment so that the net savings from letting the 16.7 miles of levees go would be relatively small. In our view, these very small potential savings are not worth the cost, delays, risk, and complexity created by requiring island-by-island, project-by-project justification of every upgrade from the HMP to the PL 84-99 standard as proposed in the DWR Draft Framework.

Given that federal assistance for costly repairs to islands is linked to achieving the Delta-specific PL 84-99 standard, the decision of whether to repair islands in the case of a breach is parallel and virtually the equivalent of whether the levees should be upgraded to the Delta-specific PL 84-99 standard. Thus, the above discussion summarizes the economic argument for our recommendation to upgrade all Delta levees to the Delta-specific PL 84-99 standard.

A second question is whether upgrading Delta lowland levees to a new higher Delta standard is economically justified. The primary economic justification for this additional upgrade is that it is a cost-effective and more financially feasible alternative to other proposals that address the coequal goals of water supply reliability and ecosystem restoration. A robust, seismically-resistant levee system would make a large improvement to water supply reliability. According to this study, $1–2 billion would be sufficient to achieve this higher standard with costs potentially increasing to $4 billion to allow for program management costs and ecosystem enhancements. This is much less expensive than the $12 billion cost estimate of isolated or dual conveyance, although dual conveyance would result in somewhat higher water exports. Water exporters have expressed concerns about whether the $12 billion isolated conveyance is cost-effective and have yet to develop a viable finance plan. Not only are upgraded levees less costly, but they provide a much broader set of benefits. While water exporters would have to pay all the costs of isolated conveyance, they could share the much lower costs of levee upgrades with others.

Water supply is not the only major infrastructure in the Delta that requires protection from seismic risk. Although they were not the focus of the 2009 Delta Reform Act, transportation, energy, and in-Delta water supplies are also critical infrastructure vulnerable to a seismic event. Upgraded levees are a cost-effective joint solution to the problem, rather than a more costly system by system approach. The infeasibility and extreme cost of the system-by-system approach is evidenced by the earlier discussion of the DRMS Phase 2 trial scenarios. Individually protecting Delta highways by building on piers cost $6 billion, individually protecting energy and aqueducts in a south Delta infrastructure corridor cost $4 billion, and individually protecting water exports costs $12 billion. The total cost of individualized solution approach is in excess of $20 billion, and some systems, not to mention in-Delta lives and property, have received no additional protection with the system-by-system approach.

This proposal to make the Delta levees more resistant to earthquake loadings is a logical extension of other seismic retrofit work that has been conducted in the Bay-Delta region since the 1989 Loma Prieta earthquake. These upgrades have already been performed for highways and bridges, dams, water supply systems, and the BART system. The Delta levees are the last major infrastructure element in the Bay-Delta region that needs to be upgraded to modern seismic standards. In order to put the proposed spending of a further $1-4 billion on Delta levees in perspective, it is noted that the Water System Improvement Program of the San Francisco Public Utilities Commission, which is basically a seismic upgrade of the Hetch-Hetchy aqueduct system, is costing $4.6 billion.[48]

Improvement of lowland levees to this standard means that they might also meet the Urban Levee Design Standard but that does not mean that it would be appropriate to construct higher-density housing behind them. It would not. The argument advanced by some that improvement

[48]http://sfwater.org/index.aspx?page=115

of the Delta levees to a higher standard would lead to urbanization assumes a set of other regulatory controls would disappear and that a market would suddenly appear for an urbanized Delta. The Delta Protection Commission, Stewardship Council, and five county general plans are all highly protective of a rural, agricultural Delta and have regulatory authority that would limit significant urbanization. It is true that the additional flood protection would support some reinvestment and revitalization of Legacy Communities, and might facilitate the construction of some limited new recreation and tourism facilities to support enhanced recreation. However, this is a benefit to improved levees, not a cost. Existing law requires that the Delta be protected and enhanced, albeit as an evolving place, and our professional assessment is that most lowland levees need to be improved to this higher standard in order to accomplish this and that it is economically realistic to do so.

Although the details and reasoning is a little different, the recommendation of improved levees in this study is similar to the "Fortress Delta" alternative in the 2007 PPIC report, "Envisioning Futures for the Sacramento-San Joaquin Delta.[49] Although the PPIC evaluation showed that the "Fortress Delta" was the best of the "freshwater Delta" solutions, it was rejected from further consideration in the screening analysis due to "extreme costs." The alternatives that passed the initial PPIC screening for further consideration either involved a peripheral canal estimated to cost $2–3 billion and ecosystem alternatives that do not satisfy the coequal goal of water supply reliability. Given that isolated conveyance is now estimated to cost $12-15 billion, and water supply reliability state law, our proposal for enhancing Delta levees is little more than suggesting that the 2007 PPIC rejection of the "Fortress Delta" alternative should be reconsidered in light of new information and developments.

5 Levee Improvement Strategies and Funding

Commencing in 1973, funding has been provided by the State of California to assist the Delta reclamation districts under two programs.

The Delta Levees Maintenance Subventions Program provides financial assistance to local levee-maintaining agencies for the maintenance and repair of levees in the Delta. It is authorized in the California Water Code, Sections 12980 through 12995. It has been in effect since passage of the Way Bill in 1973, which has since been modified periodically by legislation. One of these modifications provides for the inclusion of project levees in the program as long as more than 50 percent of the island is in the Primary Zone of the Delta, CWC 12980(f). Project levees in the Secondary Zone are not eligible for subventions funding. The intent of the legislation, as stated in the Water Code, is to preserve the Delta as it exists at the present time. A summary of expenditures under the subventions program is included as Table 3.[50] Through FY 2009-2010 the State has provided $147 million against a local share of $118 million for a total of $265 million. Details of the current procedures for prioritizing subvention funding and the required local cost shares are provided in the draft DWR Technical Memorandum (2011).

[49] http://www.ppic.org/main/publication.asp?i=671
[50] Provided by DWR and also included in the DWR Technical Memorandum.

Table 3 Delta Levee Subventions Maintenance Program State & Local Cost Share 1973-2010

	STATE						
Fiscal Years	Maintenance Reimburs.	Priority 1	Priority2	Priority 3	Total Reimburs.	Local Share	**Sub-Total**
	(1)	(2)	(3)	(3)			
	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	**$1,000**
1973-74	200				200	272	472
1974-75	175				175	483	658
1975-76	-				-	-	-
1976-77	190				190	395	585
1977-78	175				175	486	661
1978-79	175				175	323	498
1979-80	-				-	-	-
1980-81	-				-	-	-
1981-82	1,421				1,421	2,091	3512
1982-83	1,334				1,334	1,929	3263
1983-84	1,384				1,384	3,803	5187
1984-85	1,817				1,817	2,279	4096
1985-86	1,335				1,335	1,628	2963
1986-87	1,736				1,736	2,097	3833
1987-88	1,882				1,882	1,501	3383
1988-89	1,295	3,705			5,000	4,371	9371
1989-90	1,913	3,407			5,320	8,668	13988
1990-91	1,610	3,689			5,299	8,404	13703
1991-92	2,266	159			2,425	10,449	12874
1992-93	1,823				1,823	4,244	6067
1993-94	1,774	2,916	376	15	5,081	2,070	7151
1994-95	2,371	2,770			5,141	2,233	7374
1995-96	1,449	2,097			3,546	1,602	5148
1996-97	1,758	1,790			3,548	2,158	5706
1997-98	4,432	2,647			7,079	2,974	10053
1998-99	3,412	1,738			5,150	2,341	7491
1999-00	3,085	3,194	58		6,337	2,715	9052
2000-01	4,954	3,053	55		8,062	3,371	11433
2001-02	3,777	1,784			5,561	2,515	8076
2002-03	3,554	1,446			5,000	4,666	9666
2003-04	4,029	1,996			6,025	6,102	12127
2004-05	4,698	1,227			5,925	6,476	12401
2005-06	5,364	358			5,722	4,220	9942
2006-07	4,485	1,505			5,990	6,647	12637
2007-08	5,645	8,503	2,148		16,296	6,210	22506
2008-09	6,810	4,515	545		11,870	4,799	16669
2009-10	7,254	2,131	41		9,426	3880	13306
	89,582	**54,630**	**3,223**	**15**	**147,450**	**118,402**	**265,852**

(1) Excess maintenance over the maintenance cap and DFG costs are included in the maintenance.
(2) Priority 1 includes HMP and Bulletin 192-82 work.
(3) Priority 2 is priority 1 excess cost over $100,000 per mile cap. Priority 3 is land use changes

The Delta Levees Special Flood Control Projects provides financial assistance to local levee-maintaining agencies for rehabilitation of levees in the Delta. The program was established by the California Legislature under SB 34, SB 1065, and AB 360. The special projects program is authorized in the California Water Code, Sections 12300 through 12314. This program initially focused on flood-control projects and related habitat projects for eight western Delta Islands—Bethel,Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb Islands—and for the Towns of Thornton and Walnut Grove; in 1996 it was extended to the rest of the Delta. Details regarding the current prioritization of special projects funding and the required local cost shares are also provided in the draft DWR Technical Memorandum. Also, special project bond funding has been authorized for the protection of the Mokelumne Aqueduct, for those levees whose failure would jeopardize water conveyance through the Delta, and projects that reduce subsidence and assist in restoring the ecosystem of the Delta.

A summary of expenditures under the special projects program is included as Table 4.[51]The figure for FY 2009-10 includes $35million specially designated by the legislature for improvements to the five islands that protect the Mokelumne Aqueduct, $32 million for HMP projects, and about $26 million for Delta-specific PL 84-99 projects. The expenditures for FY 2007-8, 2008-9, and 2009-10 are larger than in previous years because of bond funding approved by the voters inPropositions 84[52] and 1E.[53] Through FY 2009-10, a total of $237 million will have been expendedthrough the special projects program.

Table 4 Delta Levee Program Special Projects State Expenditure 1989-2010

Fiscal Year	Planning & Engineering	Levee Construction	Habitat Enhancement	Total Expenditures
1989-1990	$15,000	$0	$0	$15,000
1990-1991	$5,210,000	$810,000	$0	$6,020,000
1991-1992	$709,400	$4,085,000	$0	$4,794,400
1992-1993	$668,500	$4,148,000	$0	$4,816,500
1993-1994	$140,000	$6,318,054	$0	$6,458,054
1994-1995	$300,505	$1,896,518	$0	$2,197,023
1995-1996	$30,000	$1,419,370	$0	$1,449,370
1996-1997	$513,618	$4,117,720	$0	$4,631,338
1997-1998	$609	$3,201,434	$0	$3,202,043
1998-1999	$0	$2,233,787	$4,035,000	$6,268,787
1999-2000	$80,555	$1,994,673	$4,009,134	$6,084,362
2000-2001	$199,613	$4,183,526	$3,837,381	$8,220,520
2001-2002	$0	$1,333,548	$1,138,797	$2,472,345
2002-2003	$800,985	$6,645,234	$6,961,843	$14,408,062
2003-2004	$95,979	$704,381	$1,118,243	$1,918,603
2004-2005	$188,044	$2,408,507	$972,500	$3,569,051
2005-2006	$553,989	$8,510,163	$446,193	$9,510,345
2006-2007	$922,127	$8,209,557	$59,500	$9,191,184
2007-2008	$1,606,681	$18,449,127	$144,000	$20,199,808
2008-2009	$4,115,986	$18,608,588	$0	$22,724,574
2009-2010	$2,346,311	$91,274,764	$6,117,538	$99,738,613
Totals:	**$18,497,902**	**$190,551,951**	**$28,840,129**	**$237,889,982**
Note: Funds for projects in FY 2008-2009 and FY 2009-2010 have been encumbered but in most cases have yet to be released due to recent, state-wide budgetary uncertainty.				

An additional $195millionis currently available from USACE through the CALFED Levee Stability Program. The USACE funding was authorized by the CALFED Bay Delta Authorization Act of

[51] Provided by DWR and also included the DWR Technical Memorandum.

[52] The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84) authorizes $5.388 billion in general obligation bonds to fund safe drinking water, water quality and supply, flood control, waterway and natural resource protection, water pollution and contamination control, state and local park improvements, public access to natural resources, and water conservation efforts.

[53] The Disaster Preparedness and Flood Protection Bond Act of 2006 (Proposition 1E) authorizes $4.09 billion in general obligation bonds to rebuild and repair California's most vulnerable flood-control structures to protect homes and prevent loss of life from flood-related disasters, including levee failures, flash floods, and mudslides and to protect California's drinking water supply system by rebuilding Delta levees that are vulnerable to earthquakes and storms. Proposition 84 enhances these efforts with an additional $800 million for flood-control projects.

2004 which provided for USACE participation in the then CALFED program. These funds are specifically for raising levees to the Delta-specific PL 84-99 standard which was the goal of that program.

The total investment in Delta levees since the inception of these programs will be $698million plus the local shares for the special projects and the CALFED Levee Stability Program once the funding in the pipeline is expended. The fact that over $351millionof this has already been spent is reflected in the generally improved condition of the levees. Also, because levees tend to fail at their weakest point, such as where they were constructed over old sloughs, many levees have already failed and then been repaired and improved at their weakest point, with the result that the present levee system is more robust than it was before the breaches. Also, concurrent with the cessation of dredging, there has been increased placement of rock riprap on the water side of the levees. Taken together, these three observations mean that historic data on the rate of levee breaches is no longer relevant, and out-of-date data compiled on the previously weaker system should not be repeated in current reports and discussions.

Table 4-1 of the DWR Technical Memorandum provides a breakdown of the funds appropriated for expenditure in the Delta from Propositions 84 and 1E.These funds total $615million. Table 4-2 of the DWR Technical memorandum provides a breakdown of both the funds committed and the funds expended to February 2010. A total of $293 million had been committed to the subventions and special projects programs and $70 million had actually been expended at that point. The total funds committed amounted to $492 million and the total funds expended amount to $166 million, so that significant funds have been committed or expended for other purposes which include contracts, program delivery, emergency, the urban and non-urban levee evaluation programs, the Sacramento bank restoration program, and bond servicing costs. Approximately $123 million remain uncommitted.

Improvement of Delta levees from at or about the HMP standard to the Delta-specific PL 84-99 standard costs in the order of $1-2 million per mile,[54] the biggest variable being whether suitable borrow material is available on-island or whether it has to be trucked or barged from adjacent islands. With the funds that are in the immediate pipeline plus the remaining bond funds, all the lowland Delta levees and most other Delta levees should be improved so that they are at or about the Delta-specific PL 84-99 standard. Indeed, if expenditure of the bond funds had not been delayed by State spending freezes and other issues, this standard could have been generally met already. Even after all Delta levees have been brought up to the PL 84-99 standard, some continuing funding will still be necessary to take care of unexpected settlements and other maintenance, but this funding might be at a reduced level. For budget purposes it is suggested that a sum in the order of $20 million per year should be allocated for this purpose, but, as discussed subsequently, the year-to-year spending might vary and should be balanced against funding for emergency preparedness and the setting aside of funds for future emergency response and recovery.

As noted above, both the subventions program and the special projects program make provision for the enhancement of fish and wildlife habitat in conjunction with levee improvements. Several alternatives for accomplishing this are illustrated in Figure 6 of the CALFED Levee System Integrity Program Plan including the construction of new waterside berms and the widening or rolling back of the existing levees. These improvements cost much less than the kind of setback levees discussed in the DRMS Phase 2 report, which involves construction of entirely new levees on virgin ground, and might typically cost in the order of an additional $1-2 million per

[54]Based on discussions with reclamation district engineers and DRMS Phase 2 report.

mile. The existing funding provides for a certain amount of this kind of enhancement but if the Delta Conservancy Strategic Plan and the Delta Plan call for more extensive enhancements of this kind, additional funding will be needed.

The cost of improvement of most lowland levees and selected additional levees to a higher Delta-specific standard that will provide 200-year plus protection for floods, earthquakes and sea-level rise and that will incorporate ecologically friendly vegetation on the water side is more difficult to estimate precisely. After improvement to the Delta-specific PL 84-99 standard, levees that do not contain saturated, loose sands may come close to meeting this standard although they would still benefit from wider crowns. Additional width also makes planting on the water side, which is desirable for a number of reasons and may be required by the Delta Plan, much more feasible. Determination of which levees do require additional improvement will require more detailed studies,but prioritization of further improvements is relatively straightforward and does not necessarily require risk analyses or cost-benefit studies. Regardless of whether or not they contain sands susceptible to liquefaction, most lowland levees should be improved to this higher standard because they face the most immediate threat from possible sea-level rise and help prevent salinity intrusion. Certain other levees which are judged to be critical to protecting infrastructure might also be improved to this higher standard if they are shown to contain sands that are susceptible to liquefaction. Figure 16provides an initial indication of which islands and tracts might be considered to have relatively high priority for further improvements. These further improvements might cost in the order of an additional $2-3 million per mile. If it is assumed that this improvement is required over 300–600 miles of non-project, non-urban levees, the total cost might be as low as $1billion. However, for general planning and budgeting purposes, it might be desirable to use a higher number like $2billion. The biggest variable in these estimates is whether or not suitable fill is available on the same island or has to be trucked or barged in. That in turn is both a function of the availability of the materials and the cooperation of the landowners,for on-island borrowing may take some land out of agricultural production. The above estimates assume a combination of on- and off-island borrow sources. If only on-island borrow is used, these cost might be reduced by as much as 50 percent. Alternately, if the regulatory impediments to dredging in the Delta are resolved, good-quality fill material could be obtained for a cost comparable to that of on-island borrow. While there are other potential uses for the dredge spoils that will result from either deepening of the deep-water ship channels or from maintenance dredging, their use for levee improvements would provide a means to keep down the cost of those improvements. These figures also assume that design and construction are executed by the local reclamation districts. If managed directly by DWR or USACE, these costs should be multiplied by a factor of as much as 2 or 3. Costs for non-urban and non-project levee improvements are much lower than costs for improvementsto urban levees, which have to factor in encroachments and penetrations and where there is often no land available for widening the levees. This has resulted in the widespread use of deep-cutoff walls that are installed through the existing levees. In addition, there are significant bureaucratic issues which add to the cost, especially when there are many landowners involved. This results in the “soft costs” being as much as 50 percent of the actual construction costs on these projects. Although the possible need to take a strip of agricultural land on the Delta islands and the need to move existing drainage channels, siphons, and pumps are still issues, the cost implications are much smaller for Delta levees and only a relatively small number of landowners have to be accommodated.

The estimated cost of $1-2 billion for improving Delta levees beyond the PL 84-99 standard that is given above not only assumes that the work would be executed by the reclamation districts but also that engineering and permitting costs are no greater than they are at present. This figure also provides only for basic levee construction on existing alignments, not for planting and other environmentally-friendly enhancements. While planting vegetation on the water side of widened levees would add little to this cost, the creation of waterside berms or rolling the levee back as previously discussed in connection with improvements to the PL 84-99 standard might add 50 to 100 percent to the cost. Construction of setback levees on a new alignment would involve land acquisition issues and add significantly to the cost, especially where the setback levee is constructed over peat that has not previously been consolidated.

There are special considerations for levees that protect Legacy Communities in the Delta. Detailed estimation of the likely cost of improving those levees awaits policy decisions that have not yet been made. However, if the levees on the relevant islands are upgraded to the proposed new Delta standard, the Legacy Communities,and also industrial/commercial facilities that serve Delta agriculture such as wineries, crush-pads, and cold storage facilities, would automatically be afforded superior flood protection and special “ring levees” should not be required. In many cases superior flood protection is in fact already provided to these communities and facilities by the existing project levees. For instance, the project levee that borders the Sacramento Riverin Walnut Creek East already has a wide crown, exceeding 50 feet at some locations, in order to accommodate a two-lane highway with parking on either side. While some additional improvements might be required elsewhere to protect legacy communities, the issue is more one of non-compliance with vegetation and encroachment and calculated seepage gradient requirements that are included in various USACE and FEMA guidelines and policies, rather than real flood risk. This issue could be addressed much more cost-effectively by granting variations from national policies rather than requiring unnecessary construction which might destroy the communities that are trying to be protected.

There are three potential sources of funding from within the Delta for maintenance, improvements, and emergency response:(1) the traditional funding from the landowners, who also make in-kind contributions to inspection and maintenance; (2) the owners of the infrastructure that passes through the Delta; and (3) the agencies that convey water through the Delta. The Delta Stewardship Council has proposed the creation of a new agency, the Delta Flood Risk Management Assessment District, with fee assessment authority. Local government officials in the Delta have expressed concerns about this proposal, and have expressed a preference for a joint powers authority (JPA) of the five counties or the Delta Protection Commission take on this role. Regardless of the entity, and leaving politics aside and just looking at this as an engineering management and risk reduction issue, it would be beneficial for a Delta region-centric entity to allocate the funding of Delta levee improvements once the present bond funding is exhausted, or even sooner. This entity should also be the entitythat is responsible for coordinating emergency preparedness and response because of the trade-off that has been previously discussed of investments in levee improvements and in emergency preparedness and response. Only if funding of both levee improvements and emergency preparedness response and recovery is controlled by a single entity whose prime concern is the protection and enhancement of the Delta in addition to consistency with the coequal goals, will it be possible to make a rational and efficient allocation of the available funds.

In addition to the funding of the improvement of selected levees to the higher Delta-specific standard, continuing funding will be required for maintenance of the existing levees and for emergency preparedness response and recovery. It has been suggested above that $20 million per year might be an appropriate sum for continuing maintenance of all Delta levees, but this figure might vary from year to year as more or less money is put into emergency preparedness response and recovery. A total sum in the order of $50 million per year might be appropriate to cover both maintenance and inspection and emergency preparedness. Some fraction of this sum should be set aside each year to provide for emergency response and recovery to supplement any fund that the State has established for that purpose in the meantime. To put this sum into perspective, although the total cost should not be borne by either highway users or water conveyance alone, if it were borne by highway users, there would need to be a toll of $2 on each use of the state highways in the Delta and if it were borne by the state and federal water contractors, there would need to be an additional charge of $10 per acre-foot, assuming average exports of 5 maf. It would also be entirely reasonable that the state and federal governments contribute funding to this entity. If it is the policy of the State to protect and enhance the Delta because that is judged to be of benefit to the region and the state, then it becomes the State's responsibility to provide funding that could, for instance, be directed primarily to widening levees so that they can accommodate vegetation on the water side and allow construction of improved recreational and tourism facilities that benefit the entire region and beyond. Outside its operation of the Central Valley Project, the federal government has interests and obligations that include the continuing downstream effects of hydraulic mining on federal lands, navigable waterways, and national economic security.

Implementation of the necessary improvements to Delta levees would be greatly helped byreducing or eliminating regulatory impediments to action by the creation of a one-stop permitting system for selected activities within the Delta including dredging, levee construction, and ecosystem restoration.

6 Periodic Update of the Flood Management Plan for the Delta

One of the four specific directives regarding the Economic Sustainability Plan that was given in the 2009 legislation is to include "comments and recommendations to the Department of Water Resources concerning its periodic update of the flood management plan for the Delta." These recommendations are:

1. Update the expected maximum water surface elevations in the Delta taking into account both the findings and the recommendations of the Central Valley Flood Protection Plan and climate change considerations. This should be done as soon as possible without waiting for the 2017 update of the Central Valley Flood Protection Plan.

2. Make provision in the Central Valley Flood Protection Plan and otherwise for re-activation of historic flood plains upstream from the Delta and by additional flood bypasses, such as the proposed Lower San Joaquin River Flood Bypass, in order to reduce peak water surface elevations in the Delta.

3. Reaffirm that it is the policy of the State to improve and maintain all non-project levees to at least the Delta-specific PL 84-99 standard.

4. Establish an additional policy to improve most "lowland" levees and selected other levees to a higher Delta-specific standard that more fully addresses the risks due to earthquakes, extreme floods, and sea-level rise, allows for improved flood fighting and emergency response, provides improved protection for legacy communities, and allows for growth of vegetation on the water side of levees to improve habitat. Define this standard in more detail as necessary.

5. Cooperate with other state and federal agencies to facilitate the renewed use of appropriate dredging in the Delta.

6. Establish as state policy that in the future any flooded islands will be recovered and that existing flooded islands should be restored as tidal habitat in order to reduce the loadings on adjacent islands in addition to providing ecosystem benefits.